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Aggregate Resources Inventory of
Raleigh and Harwich Townships
Kent County
Southern Ontario

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Paper 126

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Abstract

This report includes both an inventory and evaluation of sand and gravel as well as bedrock resources in Raleigh and Harwich townships. The report is part of the Aggregate Resources Inventory Program for townships and municipalities previously designated under the Pits and Quarries Control Act, now designated under the Aggregate Resources Act.

In Raleigh and Harwich townships, two areas containing considerable amounts of sand and gravel have been selected for possible resource protection at the primary level of significance.

Selected Sand and Gravel Resource Area 1 is a large buried deposit of granular material located in the vicinity of Pinehurst. This buried aggregate deposit is an important source of road-building and construction aggregate in this part of southwestern Ontario. Deleterious materials from parts of the deposit must be separated out of the draglined aggregate by the process of beneficiation. The beneficiated aggregate is suitable for a wide range of uses. The deposit contains an estimated 96 million tons (87 million tonnes), exclusive of licenced deposits.

Selected Sand and Gravel Resource Area 2 is a long beach ridge-spit complex related to the abandoned shoreline of glacial Lake Warren. The deposit contains an estimated 560 million tons (510 million tonnes) of sand and gravel, exclusive of licenced deposits. However, high percentages of deleterious materials, such as shale and chert, severely restrict the use of this material.

The surficial deposits are underlain by Middle to Upper Devonian strata consisting mainly of shales and limestone of the Hamilton Group and shale of the Kettle Point Formation. Neither formation is suitable for load-bearing aggregate. In addition, much of the bedrock is covered by more than 50 feet (15 m) of drift. For these reasons, no areas of bedrock have been selected for resource protection.

Selected Resource Areas are not intended to be permanent, single land use units. They represent areas in which a major resource is known to exist and may be reserved wholly or partially for extractive development and/or resource protection.

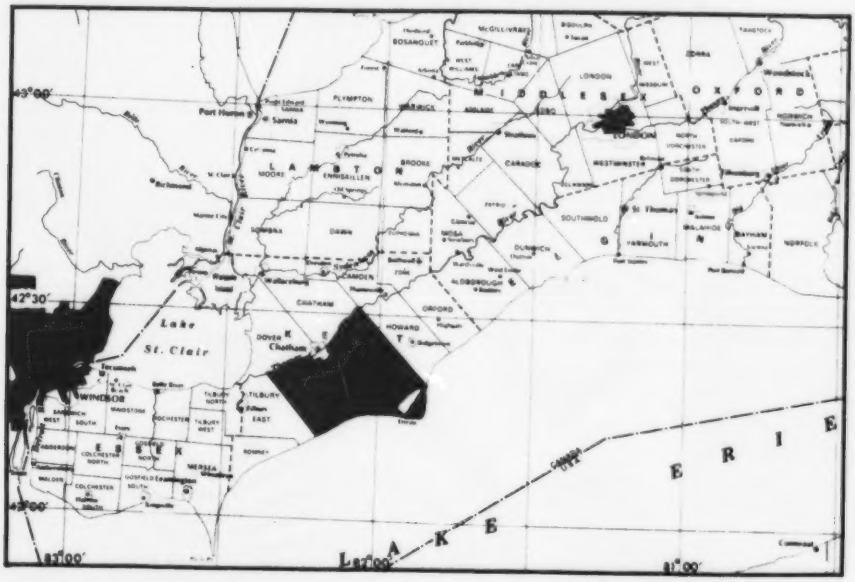

Figure 1. Key map showing the location of Raleigh and Harwich townships, scale 1:1 800 000.

Résumé

Ce rapport comprend à la fois un inventaire et une estimation des ressources en sable et en gravier ainsi que des ressources du substratum rocheux dans les cantons de Raleigh et Harwich. Il fait partie du programme sur l'Inventaire des ressources en agrégat pour les cantons régis auparavant par la Loi sur les mines et carrières, maintenant compris dans la Loi sur les ressources en agrégat.

Dans les cantons de Raleigh et Harwich, deux zones comprenant des quantités considérables de sable et gravier ont été sélectionnées comme réserves possibles de ressources de première importance.

La zone No 1, sélectionnée pour ses ressources en sable et gravier, est un important dépôt de matériau granuleux enseveli à proximité de Pinehurst. Ce dépôt est une source importante d'agrégat pour les travaux routiers et la construction dans cette partie du sud-ouest de l'Ontario. Les matériaux délétères provenant de certaines parties du dépôt doivent être séparés de l'agrégat lors de son acheminement par convoyeur selon un procédé d'enrichissement. L'agrégat enrichi convient à de nombreux usages. Le dépôt contient environ 96 millions de tonnes courtes (87 millions de tonnes métriques), à l'exclusion des dépôts enregistrés.

La zone No 2, sélectionnée pour ses ressources en sable et gravier, est un long dépôt de plage lié à l'ancien littoral du lac glaciaire Warren. Le dépôt contient environ 560 millions de tonnes courtes (510 millions de tonnes métriques) de sable et gravier, à l'exclusion des dépôts enregistrés. Cependant, l'usage de ce matériau est grandement limité par le fort pourcentage de matériaux délétères tels que les schistes argileux et le chert.

Les dépôts superficiels recouvrent les strates du Dévonien moyen et supérieur qui sont principalement constituées de schistes argileux et de calcaire appartenant au Groupe de Hamilton et de schistes argileux de la Formation de Kettle Point. Aucune de ces formations ne convient pour des agrégats à contrainte. De plus, la plupart du substratum est recouverte par plus de 50 pieds (15 m) de dépôt d'origine glaciaire. Pour toutes ces raisons, aucune partie du substratum n'a été sélectionnée comme réserve de ressources.

Les zones sélectionnées pour leurs ressources ne sont pas destinées à être réservées à un seul usage permanent. Elles représentent des zones où une ressource importante a été reconnue et peut être réservée en totalité ou en partie pour l'exploitation et/ou en tant que réserve de ressources.

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Aggregate Resources Inventory of
Raleigh and Harwich Townships
Kent County

By Staff[1] of the Engineering and Terrain Geology Section

1. Project Supervisor: I. Szoke; field work and report by R. Gorman; compilation and drafting by Staff of the Aggregate Assessment Office. The Mineral Resources Staff of Chatham District Office and Southern Region of the Ministry of Natural Resources assisted in the collection of data, field checking and review of this report.

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Introduction

Mineral aggregates, which include bedrock-derived crushed stone as well as naturally formed sand and gravel, constitute the major raw material in Ontario's road-building and construction industries. Very large amounts of these materials are used each year throughout the Province. For example, in 1987, the total tonnage of mineral aggregates extracted was 156 million tons (142 million tonnes), greater than that of any other metallic or nonmetallic commodity mined in the Province (Ontario Ministry of Northern Development and Mines 1989).

Although mineral aggregate deposits are plentiful in Ontario, they are fixed-location, nonrenewable resources which can be exploited only in those areas where they occur. Mineral aggregates are characterized by their high bulk and low unit value so that the economic value of a deposit is a function of its proximity to a market area as well as its quality and size. The potential for extractive development is usually greatest in urban fringe areas where land use competition is extreme. For these reasons the availability of adequate resources for future development is now being threatened in some areas.

Comprehensive planning and resource management strategies are required to make the best use of available resources, especially in those areas experiencing rapid development. Such strategies must be based on a sound knowledge of the total mineral aggregate resource base at both local and regional levels. The purpose of the Aggregate Resources Inventory is to provide the basic geological information required to include potential mineral aggregate resource areas in planning strategies and official plans. The reports should form the basis for discussion on those areas best suited for possible extraction. The aim is to assist decision-makers in protecting the public well-being by ensuring that adequate resources of mineral aggregate remain available for future use.

This report is a technical background document, based for the most part on geological information and interpretation. It has been designed as a component of the total planning process and should be used in conjunction with other planning considerations, to ensure the best use of a municipality's resources.

The report includes an assessment of sand and gravel resources as well as a discussion on the potential of bedrock-derived aggregate. The most recent information available has been used to prepare the report. As new information becomes available, revisions may be necessary.

Part I — Inventory Methods

FIELD AND OFFICE METHODS

The methods used to prepare the report primarily involve the interpretation of published geological data such as bedrock and surficial geology maps and reports (*see* References) as well as field examination of potential resource areas. Field methods include the examination of natural and man-made exposures of granular material. Most observations are made at quarries and sand and gravel pits located from records held by the Ontario Ministry of Transportation, the Ontario Geological Survey, and by Regional and District Offices of the Ontario Ministry of Natural Resources. Observations made at pit sites include estimates of the total face height and the proportion of gravel- and sand-sized fragments in the deposit. Observations are also made of the shape and lithology of the particles. These characteristics are important in estimating the quality and quantity of the aggregate. In areas of limited exposure, subsurface materials may be assessed by hand augering and test pitting, supplemented by test hole drilling, and geophysical surveys using hammer seismic equipment. The symbols for and locations of sample sites, test hole sites, and geophysical traverse lines are noted on Map 1.

Deposits with potential for further extractive development or those where existing data are scarce, are studied in greater detail. Representative layers in these deposits are sampled in 25- to 100-pound (11 to 45 kg) units from existing pit faces or from test pits. The samples are analysed for grain size distribution, and in some cases absorption, Los Angeles abrasion, and Magnesium Sulphate soundness tests and petrographic analyses are carried out. Analyses are performed either in the laboratories of the Soils and Aggregates Section, Engineering Materials Office, Ontario Ministry of Transportation, or in the Geoscience Laboratory, Ontario Geological Survey.

The field data are supplemented by pit information on file with the Soils and Aggregates Section of the Ontario Ministry of Transportation. Data contained in these files include field estimates of the depth, composition and "workability" of deposits, as well as laboratory analyses of the physical properties and chemical suitability of the aggregate. Information concerning the development history of the pits and acceptable uses of the aggregate is also recorded. The location, size and depth of extraction of pits licenced under the Aggregate Resources Act are obtained from records held by Regional and District Offices of the Ontario Ministry of Natural Resources. The co-operation of the above-named groups in the compilation of inventory data is gratefully acknowledged.

Aerial photographs at various scales are used to determine the continuity of deposits, especially in areas where information is limited. Water well records, held by the Ontario Ministry of the Environment, are used in some areas to corroborate deposit thickness estimates or to indicate the presence of buried granular material. These records are used in conjunction with other evidence.

Topographic maps of the National Topographic System, at a scale of 1:50 000, are used as a compilation base for the field and office data. The information is then transferred to a base map, also at a scale of 1:50 000. These base maps are prepared by the Land and Resource Information Branch, Ontario Ministry of Natural Resources with information taken from maps of the National Topographic System by permission of Energy, Mines and Resources Canada, for presentation in the report.

RESOURCE TONNAGE CALCULATION TECHNIQUES

SAND AND GRAVEL RESOURCES

Once the interpretative boundaries of the aggregate units have been established, quantitative estimates of the possible resources available can be made. Generally, the volume of a deposit can be calculated if its areal extent and average thickness are known or can be estimated. The computation methods used are as follows. First, the area of the deposit, as outlined on the final base map, is calculated in acres. The thickness values used are an approximation of the deposit thickness, based on the face heights of pits developed in the deposit or on subsurface data such as test holes and water well logs. Original tonnage values can then be calculated by multiplying the volume of the deposit by 2500 (the density factor). This factor is approximately the number of tons in a one-foot (0.3 m) thick layer of sand and gravel, one acre (0.4 ha) in extent, assuming an average density of 110 pounds per cubic foot (1766 kg/m^3).

Tonnage = Area x Thickness x Density Factor

Tonnage calculated in this manner must be considered only as an estimate. Furthermore, such tonnages represent amounts that existed prior to any extraction of material (i.e., original tonnage) (Table 1, Column 4).

The Selected Sand and Gravel Resource Areas in Table 3 are calculated in the following way. Two successive subtractions are made from the total area. Column 3 accounts for the number of acres unavailable because of the presence of permanent cultural features and their associated setback requirements. Column 4 accounts for those areas that have previously been extracted (e.g., wayside and abandoned pits are included in this category). The remaining figure is the area of the deposit currently available for extraction (Column 5). The available area is then multiplied by the estimated deposit thickness and the density factor (Column 5 x Column 6 x 2500) to give an estimate of the sand and gravel tonnage

(Column 7) presently available for extractive development and/or resource protection.

Reserve estimates are calculated for deposits of primary significance. Reserve estimates for deposits of secondary and tertiary significance are not calculated in Table 3, however, the aggregate potential of these deposits is discussed in the report.

BEDROCK RESOURCES

The method used to calculate resources of bedrock-derived aggregate is much the same as that described above. The areal extent of bedrock formations overlain by less than 50 feet (15 m) of unconsolidated overburden is determined from bedrock geology maps, drift thickness and bedrock topography maps, and from the interpretation of water well records. The measured extent of such areas is then multiplied by the estimated quarriable thickness of the formation, based on stratigraphic analyses and on estimates of existing quarry faces in the unit. In some cases a standardized estimate of 60 feet (18 m) is used for thickness. Volume estimates are then multiplied by the density factor [the estimated weight in tons of a one-foot (0.3 m) thick section of rock, one acre (0.4 ha) in extent].

Resources of dolostone are calculated using a density factor of 165 pounds per cubic foot (2649 kg/m^3) or 3600 tons per acre (8070 t/ha). Sandstone resources are calculated using a density estimate of 146 pounds per cubic foot (2344 kg/m^3) and shale resources are calculated with a factor of 150 pounds per cubic foot (2408 kg/m^3).

UNITS AND DEFINITIONS

Although most of the measurements and other primary data available for resource tonnage calculations are given in Imperial units, Metric units have also been given in the text and on the tables which accompany the report. The Metric equivalent of the data is shown in brackets after or directly below the corresponding Imperial figures. Data are generally rounded off in accordance with the Ontario Metric Practice Guide (Metric Committee 1975).

The tonnage estimates made for sand and gravel deposits are termed possible resources (*see* Glossary, Appendix B) in accordance with terminology of the Ontario Resource Classification Scheme (Robertson 1975, p.7) and with the Association of Professional Engineers of Ontario (1976).

Part II — Data Presentation and Interpretation

Three maps, each portraying a different aspect of the aggregate resources in the municipality, accompany the report. Map 1, "Distribution of Sand and Gravel Deposits", gives a comprehensive inventory of the sand and gravel resources in the report area. Map 2, "Selected Sand and Gravel Resource Areas", shows those deposits which are considered to represent the largest and/or highest quality resources in the area. Map 3, "Bedrock Resources" shows the distribution of bedrock formations, the thickness of overlying unconsolidated sediments, and identifies the Selected Bedrock Resource Areas.

MAP 1: DISTRIBUTION OF SAND AND GRAVEL DEPOSITS

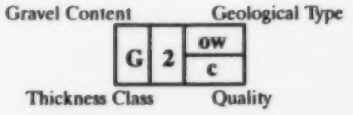
Map 1 is derived from existing surficial geology maps of the area or from aerial photograph interpretation in areas where surficial mapping is incomplete. The map shows the extent and quality of sand and gravel deposits within the study area and the present level of extractive activity.

On the map, gravel deposits are indicated by dark brown shading while sand deposits are shaded light brown. The present level of extractive activity is also indicated. Those areas which are licenced for extraction under the Aggregate Resources Act are shown by a solid outline and identified by a number which refers to the pit descriptions in Table 2. Each description notes the owner/operator, location and licenced acreage of the pit, as well as the estimated face height and percentage gravel. A number of unlicenced pits (abandoned pits or wayside pits operating on demand under authority of a permit) are identified by a numbered dot on Map 1 and described in Table 2. Similarly, test hole locations appear on Map 1 as a point symbol and are described in Table 7. Geophysics lines are shown on Map 1 by a line symbol and are interpreted in Table 8.

Map 1 also presents a summary of available information related to the quality of aggregate contained in all the known aggregate deposits in the study area. Much of this information is contained in the symbols which are found on the map. The Deposit Symbol appears for each mapped deposit and summarizes important genetic and textural data. The Texture Symbol is a circular proportional diagram which displays the grain size distribution of the aggregate in areas where bulk samples were taken.

DEPOSIT SYMBOL

The Deposit Symbol is similar to those used in soil mapping and land classification systems commonly in use in North America. The components of the symbol indicate the gravel content, thickness of material, origin (type) and quality limitations for every deposit shown on Map 1. These components are illustated by the following example:



This symbol identifies an outwash deposit 10 to 20 feet (3 to 6 m) thick containing more than 35% gravel. Excess silt and clay may limit uses of the aggregate in the deposit.

The "gravel content" and "thickness class" are basic criteria for distinguishing different deposits. The "gravel content" symbol is an upper case "S" or "G". The "S" indicates that the deposit is generally "sandy" and that gravel-sized aggregate (greater than 4.75 mm) makes up less than 35% of the whole deposit. "G" indicates that the deposit contains more than 35% gravel.

The "thickness class" indicates a depth range which is related to the potential resource tonnage for each deposit. Four thickness class divisions have been established as shown in the legend for Map 1.

Two smaller sets of letters, divided from each other by a horizontal line, follow the thickness class number. The upper series of letters identifies the geologic deposit type (the deposit types are summarized with respect to their main geologic and extractive characteristics in Appendix C) and the lower series of letters identifies the main quality limitations that may be present in the deposit as discussed in the next section.

TEXTURE SYMBOL

The Texture Symbol provides a more detailed assessment of the grain size distribution of material sampled during field study. These symbols are derived from the information plotted on the aggregate grading curves found in the report. The relative amounts of gravel, sand, and silt and clay in the sampled material are shown graphically in the Texture Symbol by the subdivision of a circle into proportional segments. The following example shows a hypothetical sample consisting of 30% gravel, 60% sand and 10% silt and clay:

MAP 2: SELECTED SAND AND GRAVEL RESOURCE AREAS

Map 2 is an interpretative map derived from an evaluation of the deposits shown on Map 1. The deposits identified on Map 2 are those which are considered to be im-

portant in ensuring an adequate resource base for the future.

All the selected sand and gravel resource areas are first delineated by geological boundaries and then classified into three levels of significance: primary, secondary and tertiary. Each area of primary significance is given a deposit number and all such deposits are shown by dark red shading on Map 2.

Selected Sand and Gravel Resource Areas of primary significance are not intended to be permanent, single land use units. They represent areas in which a major resource is known to exist and may be reserved wholly or partially for extractive development and/or resource protection.

Deposits of secondary significance are indicated by light red shading on Map 2. Such deposits are believed to contain significant amounts of sand and gravel. Although deposits of secondary significance are not considered to be the "best" resources in the report area, they may contain large quantities of sand and gravel and should be considered as part of the aggregate supply of the area.

Areas of tertiary significance are outlined on the map by a solid line but have no shading. They are not considered to be important resource areas because of their low available resources, or because of possible difficulties in extraction. Such areas may be useful for local needs but are unlikely to support large-scale development.

The process by which deposits are evaluated and selected involves the consideration of two sets of criteria. The main selection criteria are site specific, related to the characteristics of individual deposits. Factors such as deposit size, aggregate quality, and deposit location and setting are considered in the selection of those deposits best suited for extractive development. A second set of criteria involves the assessment of local aggregate resources in relation to the quality, quantity, and distribution of resources in the region in which the report area is located. The intent of such a process of evaluation is to ensure the continuing availability of sufficient resources to meet possible future demands.

SITE SPECIFIC CRITERIA

Deposit Size

Ideally, selected deposits should contain available sand and gravel resources large enough to support a commercial pit operation using a stationary or portable processing plant. In practice, much smaller deposits may be of significant value depending on the overall reserves in the rest of the municipality. Generally, deposits in Class 1 [greater than 20 feet (6 m) thick] and containing more than 35% gravel are considered to be most favourable for commercial development. Thinner deposits may be valuable in municipalities with low total resources.

Aggregate Quality

The limitations of natural aggregates for various uses result from variations in the lithology of the particles composing the deposit, and from variations in the size distribution of these particles.

Four indicators of the quality of aggregate may be included in the deposit symbols on Map 1. They are: gravel content (G or S), fines (C), oversize (O) and lithology (L).

Three of the quality indicators deal with grain size distribution. The gravel content (G or S) indicates the suitability of aggregate for various uses. Deposits containing at least 35% gravel in addition to a minimum of 20% material greater than the 26.5 mm sieve are considered to be the most favourable extractive sites, since this content is the minimum from which crushed products can be economically produced.

Excess fines (high silt and clay content) may severely limit the potential use of a deposit. Fines content in excess of 10% may impede drainage in road subbase aggregate and render it more susceptible to the effects of frost action. In asphalt aggregate, excess fines hinder the bonding of particles. Deposits known to have a high fines content are indicated by a "C" in the quality portion of the Deposit Symbol.

Deposits containing more than 20% oversize material [greater than 4 inches (10 cm) in diameter] may also have use limitations. The oversize component is unacceptable for all concrete aggregate and for road-building aggregate, so it must be either crushed or removed during processing. Deposits known to have an appreciable oversize component are indicated by an "O" in the quality portion of the Deposit Symbol.

Another indicator of the quality of an aggregate is lithology. Just as the unique physical and chemical properties of bedrock types determine their value for use as crushed rock, so do various lithologies of particles in a sand and gravel deposit determine its suitability for various uses. The presence of objectionable lithologies such as chert, siltstone and shale, even in relatively small amounts, can result in a reduction in the quality of an aggregate, especially for high quality uses such as concrete and asphalt. Similarly, highly weathered, very porous and friable rock can restrict the quality of an aggregate. Deposits known to contain objectionable lithologies are indicated by an "L" in the quality component of the Deposit Symbol.

If the Deposit Symbol shows either "C", "O", or "L" or any combination of these indicators, the quality of the deposit is considered to be reduced for some uses of the aggregate. No attempt is made to quantify the degree of limitation imposed. Assessment of the four indicators is made from published data, from data contained in files of both the Ontario Ministry of Transportation and the Engineering and Terrain Geology Section of the Ontario Geological Survey, and from field observations.

Quality data may also appear in Table 9, where the results of aggregate quality tests are listed by test type and sample location. The types of tests conducted and

the test specifications are explained in Appendixes B and E, respectively.

Analyses of unprocessed samples obtained from test holes, pits or sample sites are plotted on grain size distribution graphs. On the graphs are the Ontario Ministry of Transportation's gradation specification envelopes for aggregate products: Granular Base Course A, B and C, Hot-Laid Asphaltic Sand Nos. 1,2,3,4 and 8, and concrete sand. By plotting the gradation curves with respect to the specification envelopes, it can be determined how well the unprocessed sampled material meets the criteria for each product. These graphs, called Aggregate Grading Curves, follow the tables in the report.

Location and Setting

The location and setting of a resource area has a direct influence on its value for possible extraction. The evaluation of a deposit's setting is made on the basis of natural and man-made features which may limit or prohibit extractive development.

First, the physical context of the deposit is considered. Deposits with some physical constraint on extractive development, such as thick overburden or high water table, are less valuable resource areas because of the difficulties involved in resource recovery. Second, permanent man-made features, such as roads, railways, powerlines, and housing developments, which are built on a deposit, may prohibit its extraction. The constraining effect of legally required setbacks surrounding such features is included in the evaluation. A quantitative assessment of these constraints can be made by measurement of their areal extent directly from the topographic maps. The area rendered unavailable by these features is shown for each resource area in Table 3 (Column 3).

The assessment of sand and gravel deposits with respect to local land use and to private land ownership is an important component of the general evaluation process. These aspects of the evaluation process are not considered further in this report, but readers are encouraged to discuss them with personnel of the pertinent District Office of the Ontario Ministry of Natural Resources.

REGIONAL CONSIDERATIONS

In selecting sufficient areas for resource development, it is important to assess both the local and the regional resource base, and to forecast future production and demand patterns.

Some appreciation of future aggregate requirements in an area may be gained by assessing its present production levels and by forecasting future production trends. Such an approach is based on the assumptions that production levels in an area closely reflect the demand and that the present production "market share" of an area will remain roughly at the same level.

The aggregate resources in the region surrounding a municipality should be assessed in order to properly evaluate specific resource areas and to adopt optimum resource management plans. For example, a municipality that has large resources in comparison to its surrounding region constitutes a regionally significant resource area. Municipalities with high resources in proximity to large demand centres, such as metropolitan areas, are special cases.

Although an appreciation of the regional context is required to develop comprehensive resource management techniques, such detailed evaluation is beyond the scope of this report. The selection of resource areas made in this study is based primarily on geological data or on considerations outlined in preceding sections.

MAP 3: BEDROCK RESOURCES

Map 3 is an interpretative map derived from bedrock geology, drift thickness and bedrock topography maps, water well data from the Ontario Ministry of the Environment, oil and gas well data from the Petroleum Resources Section (Ontario Ministry of Natural Resources) and from geotechnical test hole data from various sources. Map 3 is based on concepts similar to those outlined for Maps 1 and 2, but displays both the inventory and evaluation on the one map.

The geological boundaries of the bedrock units are shown by a dashed line. Isolated outcrops are indicated by an "X". Three sets of contour lines delineate areas of less than 3 feet (1 m) of drift, areas of 3 to 25 feet (1 to 8 m) of drift, and areas of 25 to 50 feet (8 to 15 m) of drift. The extent of these areas of thin drift are shown by three shades of blue. The darkest shade indicates where bedrock outcrops or is within 3 feet (1 m) of the ground surface. These areas constitute potential resource areas because of their easy access. The medium shade indicates areas where drift cover is up to 25 feet (8 m) thick. Quarrying is possible in this depth of overburden and these zones also represent potential resource areas. The lightest shade indicates bedrock areas overlain by 25 to 50 feet (8 to 15 m) of overburden. These latter areas constitute resources which have extractive value only in specific circumstances. Outside of these delineated areas, the bedrock can be assumed to be covered by more than 50 feet (15 m) of overburden, a depth generally considered to be too great to allow economic extraction (unless part of the overburden is composed of economically attractive deposits).

Other inventory information presented on Map 3 is designed to give an indication of the present level of extractive activity in the report area. Those areas which are licenced for extraction under the Aggregate Resources Act are shown by a solid outline and identified by a number which refers to the quarry descriptions in Table 5. Each description notes the owner/operator, location, licenced acreage and an estimate of face height. Unlicenced quarries (abandoned quarries or wayside quarries operating on demand under authority of a permit) are also identified and numbered on Map 3 and de-

scribed in Table 5. Two additional symbols may appear on the map. An open dot indicates the location of a selected water well which penetrates bedrock. The overburden thickness is shown in feet beside the open dot. Similarly, test hole locations appear as a point symbol with the depth to bedrock shown in feet beside it. The test holes may be further described in Table 7.

SELECTION CRITERIA

Criteria equivalent to those used for sand and gravel deposits are used to select bedrock areas most favourable for extractive development.

The evaluation of bedrock resources is made primarily on the basis of performance and suitability data established by laboratory testing at the Ontario Ministry of Transportation. The main characteristics and uses of the bedrock units found in southern Ontario are summarized in Appendix D.

Deposit "size" is related directly to the areal extent of thin drift cover overlying favourable bedrock formations. Since vertical and lateral variations in bedrock units are much more gradual than in sand and gravel deposits, the quality and quantity of the resource are usually consistent over large areas.

Quality of the aggregate derived from specific bedrock units is established by the performance standards previously mentioned. Location and setting criteria and regional considerations are identical to those for sand and gravel deposits.

SELECTED RESOURCE AREAS

Selection of Bedrock Resource Areas has been restricted to a single level of significance. Three factors support this approach. First, quality and quantity variations are gradual. Second, the areal extent of a given quarry operation is much smaller than that of a sand and gravel pit producing an equivalent tonnage of material, and third, since crushed bedrock has a higher unit value than sand and gravel, longer haul distances can be considered. These factors allow the identification of alternative sites having similar development potential. The Selected Areas, if present, are shown on Map 3 by a line pattern and the calculated available tonnages are given in Table 6.

Selected Bedrock Resource Areas shown on Map 3 are not permanent, single land use units. They represent areas in which a major bedrock resource is known to exist and may be reserved wholly or partially for extractive development and/or resource protection.

Part III - Assessment of Aggregate Resources in Raleigh and Harwich Townships

LOCATION AND POPULATION

Raleigh and Harwich townships occupy a total area of 171 060 acres (69 228 ha) in the south-central part of Kent County, southwestern Ontario. The report area extends from Lake Erie north to the Thames River, and is bound by Howard and Tilbury East townships to the east and west, respectively. Rondeau Provincial Park is located at the southeastern extremity of Harwich Township. The townships are shown on portions of the Romney (40 J/1), Chatham (40 J/8), Wallaceburg (40 J/9) and Ridgetown (40 I/5) map sheets of the National Topographic System, at a scale of 1:50 000.

Since 1975, the population of the report area has remained relatively stable, experiencing only minor fluctuations. The total population, exclusive of the incorporated municipalities, decreased by approximately 4% from 12 343 in 1975 to 11 836 in 1985 (Ontario Ministry of Treasury, Economics and Intergovernmental Affairs 1976a; Ontario Ministry of Municipal Affairs 1988).

The city of Chatham and town of Blenheim are the major trade and retail centres in the report area. Figures from previous years indicate that the populations of these centres have increased by approximately 10% and 15%, respectively, from 1975 to 1985 (Ontario Ministry of Treasury, Economics and Intergovernmental Affairs 1976a; Ontario Ministry of Municipal Affairs 1988). The villages of Erieau and Erie Beach and a number of small hamlets including Rondeau Park, North Buxton, Shrewsbury, Cedar Springs, Charing Cross and Merlin are also located in the townships. Seasonal recreational inhabitants occupy waterfront cottages in Rondeau Provincial Park, and between the villages of Erieau and Erie Beach.

Population projections for Kent County as a whole indicate a possible population increase up to 23% by the year 2001 (Ontario Ministry of Treasury, Economics and Intergovernmental Affairs 1976b). In view of this predicted growth rate, the demand for both road-building and construction aggregate will likely increase.

The townships are served by a grid network of paved and gravel-surfaced township and county roads. King's highways 401, 2, 3, 40 and 51 traverse the townships and link market centres. Lines of the Canadian National Railways, Canadian Pacific Railway, and CSX Transportation (CSXT) serve the report area. Docking facilities are available at the village of Erieau to serve Great Lakes ship traffic.

PHYSIOGRAPHY AND SURFICIAL GEOLOGY

Approximately 23 000 to 10 000 years ago, during the Late Wisconsinan Substage of the Pleistocene Epoch (informally known as the "Great Ice Age"), lobes or submasses of the Laurentide Ice Sheet advanced out of the Great Lakes basins and joined to entirely cover southern Ontario. The physiography and distribution of surficial materials in Raleigh and Harwich townships, including the sand and gravel deposits shown on Map 1, are largely the result of the repeated advance and retreat of the Huron and Erie glacial lobes.

Raleigh and Harwich townships fall within three physiographic regions: the St. Clair clay plains, the Bothwell sand plain and the Erie spits (Chapman and Putnam 1984). The Essex clay plain, a subregion of the St. Clair clay plains, represents an extensive area of low relief positioned between the basins of Lake Erie and Lake St. Clair. In the study area, the Essex clay plain is essentially a gently undulating clay till plain located between the northwestern part of Raleigh Township and Lake Erie (Sado 1981). Drainage is towards Lake St. Clair by the Thames River system, but south of Blenheim several small creeks drain into Lake Erie through Rondeau Bay. The natural drainage gradient is so low that tile underdrains and an elaborate system of canals and water pumping stations are used throughout the area to provide improved drainage for satisfactory crop growth conditions.

The Bothwell sand plain is a shallow sand plain located in the northern part of the report area. The sand plain was the delta of the Thames River in glacial Lake Warren (Chapman and Putnam 1984). Glaciolacustrine, alluvial and deltaic sediments (sands, silts and clays) dominate this physiographic region (Sado 1981). The modern cuspate sand spit at Pointe Aux Pins is part of the Erie spits physiographic region and represents the most striking shoreline feature in the report area. Rondeau Bay is enclosed by this spit feature.

The report area was affected by glacial lobes that flowed out of the Lake Huron and Erie basins. The actual flow patterns were complex and changed frequently during the Wisconsinan Substage (Dreimanis and Goldthwait 1973). The oldest surface glacial deposit in the report area is a black, shale rich, clayey silt to sandy silt till which is found throughout much of the area south of King's Highway 401 (Cooper and Baker 1978; Kelly, in press). The upper 3 to 6 feet (1 to 2 m) of this till is heavily oxidized and leached of carbonates (Sado 1981). The till is exposed along the shore bluffs of Lake Erie at the extreme western end of Raleigh Township and further west into Tilbury East Township. Sections up to 62 feet (19 m) exist. A number of observations from Quaternary mapping of the area indicate that this till is a Huron lobe derived unit (Kelly, in press). This till is proposed to be of early Port Bruce Stadial age and is tentatively correlated with the Tavistock Till (Kelly, in press).

A second slightly younger clast poor, clayey silt to silt till occurs in the southeastern part of the report area. This till is well exposed along the shore bluffs of Lake Erie. Tracing of this till eastward along the Lake Erie shoreline, suggests that it correlates with the Port Stanley Till deposited about 15 000 to 14 500 years ago during the Port Bruce Stadial (Dreimanis 1977; Sado 1981). Till has very little value as an aggregate because of its excessive silt and clay content. However, immediately west of Fletcher, till leached of carbonates has been used in the manufacture of drain tile (Guillet 1967).

The continuity of the low-relief plains is interrupted by very few positive-relief features. Local relief is provided by a number of isolated sand dunes, the Charing Cross moraine, the Blenheim moraine and the abandoned shorelines that encircle it. The Charing Cross moraine was probably formed by a standstill or minor readvance of the Huron ice front as it retreated northward (Kelly, in press).

The Blenheim moraine is thought to be an interlobate feature developed between the Huron and Erie ice lobes (Chapman and Putnam 1984). Investigation of the feature during Quaternary mapping of the area (Kelly, in press) suggests that the moraine was deposited in an interlobate position with much of its sediment being derived from a Huron lobe ice source. The Erie ice lobe appears to have played only a minor role in the formation of this feature. This moraine represents the single most prominent geomorphic feature in the report area and consists of a band of irregular topography widening away from Blenheim, towards the northwest.

Slight retreat of the Huron and Erie ice lobes forced meltwaters generated at the ice fronts, to flow southwestward. Initially, the meltwaters eroded a large channel in the underlying sediments. The channel was subsequently infilled with an upward coarsening deltaic sequence of sands and gravels. This delta is exposed in the Lake Erie bluffs, southwest of Blenheim. The materials comprising this delta have been exploited for aggregate, however, poor sorting and the presence of deleterious materials severely limit the use of this aggregate (Cooper 1977).

After the Port Bruce Stadial, rapid glacial melting occurred in the report area (Mackinaw Interstadial). A subsequent glacial readvance (Port Huron Stadial) did not reach the Raleigh-Harwich area. Following retreat of the glacial ice from the area, a series of proglacial lakes developed (Leverett 1902; Dreimanis 1966, 1967; Sly and Lewis 1972). These lakes ponded between high ground to the south and west of present-day Lake Erie and glacial ice to the north and east. Evidence for the existence of some of these glacial lakes in the report area is noted.

Glacial Lake Warren had a large influence on the report area. A major Lake Warren beach sequence (3 strands), which formed about 12 500 years ago, is located in the southern part of the report area. Associated with the shorelines is a linear ridge of gravel and sandy gravel extending southwest from the Blenheim Moraine, through Cedar Springs, to the Lake Erie bluffs, where it is truncated. This deposit is interpreted to be a spit, formed in Lake Warren, by current reworking of underlying deltaic materials which had been deposited during the initial retreat of the Erie and Huron ice lobes. At Blenheim, the deposit splits and extends northeasterly along either flank of the Blenheim Moraine. The material found in this beach deposit is fine gravel with interstratified medium to coarse sand. This deposit has been a traditional supplier of fine gravel to the townships and as such is an important sand and gravel resource area. Poor sorting and the presence of deleterious materials, however, severely limit the use of this aggregate (Cooper 1977).

A thin veneer of glaciolacustrine plain sediments, consisting of silty, fine to medium sand makes up the Bothwell sand plain located in the north-central part of the report area. These sediments were deposited in the shallow parts of glacial Lake Warren. The fineness of gradation limits the aggregate potential of these glaciolacustrine deposits. Below the Lake Warren shoreline, sediments, consisting primarily of silts and clays deposited in lakes Maumee, Arkona and Warren, accumulated over the till plains. Much of the report area, especially southwest of Chatham and southeast of Blenheim, is covered by such sediments. In the past, surface clay was extracted (pit no. 40) and trucked to a large plant which once operated on the eastern outskirts of Chatham. At this plant, the clay was used in the manufacture of drain tile and brick (Guillet 1967).

The ice lobes gradually left the Lake Erie basin and parts of the adjacent Huron and Ontario basins. New drainage outlets opened and allowed the lake levels in the Erie basin to drop to the postulated Early Lake Algonquin level. Falling lake levels in the Erie basin, following Lake Warren, were punctuated by brief pauses which saw the development of short lived lakes. As a result only weak and discontinuous shoreline features developed (Calkin and Feenstra 1985).

With even further retreat of the ice margin, Lake Erie water levels fell as water drained over the Niagara Escarpment into Lake Iroquois via the modern Niagara River (Sly and Lewis 1972). This marked the end of glacial activity in the Lower Great Lakes and the beginning of the development of Early Lake Erie.

Postglacial and erosional processes have been of some importance in altering the land surface of the report area. The modern sand spit at Rondeau was formed by longshore currents carrying sand from eroded shorebluffs. Organic deposits of peat and muck exist west of Erieau. Lagoonal deposits of muck, silt and clay are confined to the Rondeau Bay area (Cooper and Baker 1978). Northwesterly winds reworking fine to medium sand from the Bothwell sand plain, have formed dunes that modify the surface of this flat feature.

EXTRACTIVE ACTIVITY

Raleigh and Harwich townships contain substantial resources of sand and gravel which are concentrated in

two main areas. In the Pinehurst area, buried aggregate has been extracted by two commercial operators. This area is the only known source in Kent County of fine and coarse aggregate, that satisfies Ministry of Transportation (MTO) specifications for concrete, hot mix asphalt and Granular Base Course (GBC) A products. In the area northeast and southwest of Blenheim, a long beach ridge-spit complex, related to the abandoned shorelines of glacial Lake Warren, has been the source of a large volume of aggregate. Most of the properties contain fine-grained aggregate suitable for the production of GBC B and select subgrade material. Consequently, the majority of the pits have a "low" pit-use rating according to the criteria established by MTO.

In Raleigh and Harwich townships, 16 sand and gravel pits are licenced for extraction. Licenced properties have a total area of 582.0 acres (235.5 ha). Records of the total annual production from all licenced sources show that the average annual production over the eleven-year period from 1974 to 1984 was 111 000 tons (101 000 tonnes) in Raleigh Township and 750 000 tons (680 000 tonnes) in Harwich Township.

The production of high-specification aggregate within the report area is inadequate to supply present market requirements. Large quantities of high-specification aggregate, such as concrete and hot-laid stone and GBC A, must be imported. The bulk of imported high quality aggregate is trucked from gravel pits in the Komoka-London area and from quarries in the Amherstburg area. High-specification aggregate can also be supplied to the area from the United States of America through the docking facilities along the St. Clair River in Moore Township, Lambton County. Quarries located as far east as Cayuga have supplied stone products to the city of Chatham by rail. A large dolostone quarry located on the south shore of Manitoulin Island could also supply high quality aggregate to the report area.

SELECTED SAND AND GRAVEL RESOURCE AREAS

Map 1 illustrates the distribution of sand and gravel deposits in Raleigh and Harwich townships. The total area occupied by these deposits is approximately 37 500 acres (15 200 ha). The deposits contain possible resources of 1430 million tons (1300 million tonnes). However, much of the fine-grained aggregate included in the calculations, has very limited potential for use as road-building or construction aggregate.

Map 2 illustrates the Selected Sand and Gravel Resource Areas. A large buried deposit of granular material has been selected at the primary level of significance. It is located in the vicinity of Pinehurst in Harwich Township and is an important source of aggregate in this part of Ontario. The deleterious materials in this deposit are removed by beneficiation. A long beach ridge-spit complex, related to glacial Lake Warren, has also been selected at the primary level of significance. The beach ridge-spit complex extends northeast from the Lake Erie shoreline in Raleigh Township through Blenheim in Harwich Township. This is a very large deposit, however, the poor quality of the aggregate contained within this deposit restricts the use of the material.

Selected Sand and Gravel Resource Area 1

A large buried aggregate deposit is located in the Pinehurst area in Harwich Township (Sado 1976). This buried deposit is an important source of road-building and construction aggregate for Kent County and portions of Essex and Lambton counties. The geological origin of this deposit has not been clearly established. It is thought that the sediments found in this deposit may have developed in an ice-contact setting. The buried aggregate, overlain by up to 23 feet (7 m) of silty sand and till, appears to directly overlie the bedrock surface (Hewitt and Karrow 1963; Sado 1983).

Two pit operators have been extracting sand and gravel from 3 licenced pits in Area 1 for a number of years. Dragline operations have been employed to extract aggregate from below the relatively high water table. During field investigations, freshly draglined material was observed to contain rounded to spheroidal fine gravel and medium to very coarse sand. Field estimates of gravel content ranged between 40 to 50%. Oversize material was noted in the two properties.

Large percentages of deleterious material including shale and chert occur in the aggregate. Huron Gravel Ltd. (pit nos. 2 and 3) employs a processing method known as heavy media separation to separate deleterious material, such as shale, from the draglined aggregate. This heavy media separation is a process of beneficiation.

Pit nos. 1 and 2 are capable of producing a wide variety of aggregate products including GBC A and B, select subgrade material, 3/4 inch (19 mm), 3/8 inch (10 mm) and 1/4 inch (6 mm) round stone. Certain crushed stone products and mortar sands are imported to pit no. 1 for blending and/or resale. High-specification concrete sand is produced in both pit nos. 1 and 2 and is supplied to ready mix and concrete block producers. The use of heavy media separation enables Huron Gravel Ltd. to supply sand and coarse aggregates for use in the hot mix asphalt industry (Deike 1973). Pit no. 2 also produces a slate-crushed product, derived from the underlying Kettle Point Formation, that is extremely popular in the area for use on private driveways.

The boundaries of this buried deposit have been based on detailed investigations conducted by Vanderveer (in press). Within the delineated areas, less than 30 feet (9 m) of till and/or silty fine sand is expected to overlie the aggregate. The aggregate may be variable in thickness but is generally expected to average 50 feet (15 m). Subsurface drilling is recommended prior to extraction to determine the extent and thickness of the buried aggregate underlying the till.

Resource Area 1 occupies 770 acres (310 ha), exclusive of licenced properties. Cultural constraints and previous extraction reduce the area currently available to 650 acres (265 ha). Assuming an average deposit thickness of 50 feet (15 m), buried aggregate resources are estimated to be 96 million tons (87 million tonnes). The deposit is easily accessible by King's Highway 401 and county roads 14 and 38.

Selected Sand and Gravel Resource Area 2

Selected Sand and Gravel Resource Area 2 is a glaciolacustrine beach ridge-spit complex related to the abandoned shorelines of glacial Lake Warren. The spit complex formed in Lake Warren as a westerly-growing feature, extending from the Blenheim moraine along King's Highway 3 to just past the hamlet of Ouvry. Although the aggregate found within this deposit is not of the highest quality, it has traditionally represented the largest source of fine gravel in the area. There has been a substantial history of sand and gravel extraction from Area 2, and many of the pits are presently overgrown and water filled.

In Area 2, 13 sand and gravel pits are licenced to operate under the Aggregate Resources Act. Nineteen identified unlicenced sources have also operated in the deposit. Faces in these pits are up to 50 feet (15 m) high and expose variable gravel contents ranging from less than 10 to 30%. Overgrown faces and water-filled floors typify more than 70% of the pits in Area 2. During field investigation, fresh excavations made in some of the pits revealed poorly sorted, rounded to spherical, fine gravel interstratified with medium to coarse sand. Faces in a few of the pits exposed well sorted interlayers of openwork clasts, commonly imbricated with shingle layers. A geophysics traverse line (RH-GT-1), completed on the floor of pit no. 10, indicated the presence of an additional 13 feet (4 m) of spit gravel and gravelly sand overlying till (Table 8).

Aggregate suitability data obtained from MTO indicate that this deposit has supplied fine-grained aggregate acceptable for GBC B and select subgrade material. In 1984, channel face samples were taken in the licenced properties by the staff of the Chatham District Office of the Ontario Ministry of Natural Resources, and were subsequently analysed by the Materials Testing Laboratories of the Soils and Aggregate Section of the Ministry of Transportation in London, Ontario. The results indicate that the sampled aggregate generally lies within the acceptable limits for select subgrade material and in most cases GBC B (Figures 4a to 8a). Pits containing crushable material are virtually non-existent in this deposit (Deike 1973). Throughout this deposit the quality of the sand and stone is unacceptable for the production of high-specification fine aggregate products.

Aggregate quality is poor because of the occurrence of large percentages of deleterious materials. The aggregate can contain between 14 and 25% black to grey shale and up to 10% chert (Cooper 1977; Holubec and DeLory 1964). The presence of the shales and chert reflects the proximity of the shale- and chert-bearing bedrock formations (Ingham and Koniuszy 1965). To improve the overall quality of the shaly gravel, it would be necessary to separate the deleterious materials from the sound aggregate.

Resource Area 2 occupies 7500 acres (3050 ha), exclusive of licenced properties. Many parts of the deposit have been sterilized by residential and urban development. Setback allowances, previous extraction and cultural constraints reduce the available area to 5000 acres (2020 ha). Based on pit face heights and selected water well data, the average thickness of usable material in the area is estimated to be 30 feet (9 m). Therefore, the sand and gravel resources total approximately 560 million tons (510 million tonnes). King's Highway 3 was built on a large part of this deposit and provides efficient transportation routes to local destinations.

BEDROCK GEOLOGY

Glacial sediments in Raleigh and Harwich townships are underlain by Middle to Upper Devonian strata consisting mainly of shale and limestone. Most of the report area is underlain by black shale of the Kettle Point Formation. A large band of older Hamilton Group shales and limestone is located south of Chatham between King's Highway 401 and Lake Erie, and in the northwest and southwest corners of Raleigh Township.

Devonian strata in this part of southwestern Ontario have a gentle regional dip of approximately 30 feet per mile (6 m/km) towards the centre of the Appalachian Basin (Winder and Sanford 1972; Sanford 1967). However, in the broad depression located between the Findlay and Algonquin arches (Chatham Sag), the strata are for the most part near-horizontal (Sanford 1967; Uyeno et al. 1982).

In most of the report area the overburden is quite thick except for a few isolated locations, mainly east of Chatham. The thickness of the overburden makes quarrying of the bedrock units for aggregate use impractical, and as a result no bedrock areas have been selected for resource protection.

The Middle Devonian Hamilton Group is the oldest unit in the report area. It occurs in a wide band south of Chatham, extending to the shore of Lake Erie. The unit also outcrops in the southwestern and northwestern part of Raleigh Township. The maximum thickness of the group in southwestern Ontario is approximately 305 feet (93 m) (Winder and Sanford 1972). The group is composed of grey shales with interbeds of crystalline and cherty limestone (Telford and Russell 1981; Uyeno et al. 1982). The group has six formations, but only the Arkona Formation is of commercial value. It is extracted at Thedford and near Arkona for the production of drainage tile. The Hungry Hollow Formation of the Hamilton Group may be acceptable for some crushed stone products and fill, with selective quarrying.

Overlying the Hamilton Group are the shales of the Upper Devonian Kettle Point Formation, which is the

youngest bedrock unit in the townships. The Kettle Point Formation underlies most of the report area, extending from the Thames River to the shore of Lake Erie. The unit lies within the downwarped area of the Chatham Sag. The formation consists of brown or black, highly fissile, bituminous shale with minor interbeds of grey-green silty shale. The lower part is characterized by the occurrence of large subspherical and elliptical limestone concretions locally known as kettles (Telford and Johnson 1984; Uyeno et al. 1982). The formation is not exposed in the report area because it is thickly drift covered, however, large blocks of the unit are commonly draglined to the surface at pit nos. 1 and 2. The formation is less than 100 feet (30 m) thick at the Chatham Sag, where it has been bevelled by postdepositional erosion. It thickens rapidly to more than 1000 feet (305 m) beneath Lake Erie (Sanford 1967; Uyeno et al. 1982). Kettle Point shale possesses little ceramic value because of its high organic and sulphur content, and has not been used for ceramic products in Ontario (Guillet 1977). Testing in Warwick Township, Lambton County by MTO has shown that this shale unit is suitable for select subgrade material because of its bituminous nature and water resistant properties (Deike 1982; Franklin and Gruspier 1983). An evaluation of the resource potential of the oil shale deposits within the formation was undertaken by the Ontario Geological Survey. Test holes RH-TH-5, 12, 14 and 15 were drilled as part of the Provincial Oil Shale Assessment Project and the core logs are found in Table 7 (Johnson 1985; Johnson et al. 1985). Test holes RH-TH-6, 7, 8, 9, 10, 11 and 13 were drilled as oil and gas exploration wells. The locations of these deep test holes are plotted on Map 3.

Devonian rocks in nearby Lambton County have been important as a source for natural gas and oil. Several onshore natural gas and oil deposits occur within the report area. Silurian and Devonian natural gas fields also exist offshore (Booth-Horst et al. 1982).

SUMMARY

The sand and gravel deposits of Raleigh and Harwich townships are the product of Late Wisconsinan glacial, postglacial and modern processes. A buried aggregate deposit and a glaciolacustrine beach ridge-spit complex have been selected for resource protection. The large deposit of buried granular material is located near Pinehurst. Beneficiated aggregate from this deposit has been used for a wide variety of aggregate products including granular base course, asphalt and concrete sand. Deleterious materials found within the glaciolacustrine beach ridge-spit complex severely restrict the uses of the aggregate, however, reserves from this deposit should be sufficient to meet local demands for low-specification products for a considerable period of time.

Bedrock units underlying Raleigh and Harwich townships include the Kettle Point Formation and the 6 formations of the Hamilton Group. With selective extraction, portions of these formations may be suitable for the production of low-specification road-building aggregate. However, because of the thick drift cover, no areas of bedrock were selected for possible resource protection.

Enquiries regarding the Aggregate Resource Inventory of Raleigh and Harwich Townships should be directed to the Aggregate Assessment Office, Ontario Geological Survey, Ontario Ministry of Northern Development and Mines, 7th Floor, 77 Grenville Street, Toronto, Ontario, M7A 1W4 [Tel. (416) 965-1663], or to the Resident Geologist, London, Southern Ontario Region, Ontario Ministry of Northern Development and Mines, P.O. Box 5463, 659 Exeter Road, London, Ontario N6A 4L6 [Tel. (519) 661-2773] or to the Ontario Ministry of Natural Resources, Chatham District Office, Box 1168, 1023 Richmond Street West, Chatham, Ontario, N7M 5J5 [Tel. (519) 354-7340].

TABLE 1. TOTAL SAND AND GRAVEL RESOURCES, RALEIGH AND HARWICH TOWNSHIPS.*

1 CLASS NO.	2 DEPOSIT TYPE (*see* Appendix C)	3 AREAL EXTENT Acres (Hectares)	4 ORIGINAL TONNAGE Millions of Tons (Tonnes)	1 CLASS NO.	2 DEPOSIT TYPE (*see* Appendix C)	3 AREAL EXTENT Acres (Hectares)	4 ORIGINAL TONNAGE Millions of Tons (Tonnes)
1	G-IC-OW	980 (395)	123 (112)		S-WD	810 (330)	16 (15)
	S-LB	10 700 (4350)	790 (720)	4	S-LB	250 (101)	2 (2)
3	S-LP	24 600 (10 000)	490 (445)		S-WD	540 (218)	7 (6)
				TOTAL FOR STUDY AREA:		37 500 (15 200)	1430 (1300)

N.B. Minor variations in tables are caused by rounding of data.

* *Identified deposit areas within the city of Chatham, town of Blenheim, hamlet of Rondeau Park, Rondeau Provincial Park and the Canadian Forces Cedar Springs Range have been omitted on all tables.*

TABLE 2. SAND AND GRAVEL PITS, RALEIGH AND HARWICH TOWNSHIPS.

1 NO.	2 MTO NO.	3 OWNER/OPERATOR	4 LOT	5 CONC.	6 LICENCED AREAS Acres (Hectares)	7 FACE HEIGHT Feet (Metres)	8 % GRAVEL
LICENCED PITS							
Harwich Township							
1	C8-4	Adams Sand & Gravel Ltd.	Pt.15, 16,17	12 LES	210.0 (84.9)	2-12 (1-4)	40-50 variable
			Pt.17	13 LES		50-60 (15-18) (below water)	
2	C8-3	Huron Gravel Ltd.	Pt.16, 17	13 LES	123.0 (49.8)	10 (3)	40-50 variable
						50-60 (15-18) (below water)	
3	-	Huron Gravel Ltd.	Pt.16	13 LES	54.7 (22.1)	10 (3)	40-50
4	C8-17	McGuigan Brothers	Pt.10	2 WCR	12.4 (5.0)	2-5 (1-2)	< 30 partially water filled
5	C8-14	Township of Harwich	Pt.10	3 WCR	26.0 (10.5)	10-25 (3-8)	20-30 partially water filled
6	C8-19	James & Gail Boker	Pt.9	4 WCR	17.6 (7.1)	15-30 (5-9)	20-30
7	-	Alfred Gore	8-11 Pt. Lot 1	4 Cedar Springs Plan	5.0 (2.0)	15-20 (5-6)	- partially backfilled
8	C8-13	Township of Harwich	Pt.8	4 WCR	13.7 (5.5)	15-30 (5-9)	20-30 overgrown
9	-	J.A. Bokor & M.K. Bokor	Pt.9	4 WCR	16.9 (6.8)	10-15 (3-5)	< 15 water filled
					479.3 (194.0)		
Raleigh Township							
10	C8-60	Cedar Springs Sand & Gravel	129	TRS	27.6 (11.2)	10-15 (3-5)	< 25
11	-	Township of Raleigh	130,131 22,23	TRS 1 LES	21.3 (8.6)	15-25 (5-8)	20-30
12	C8-46	R. Leque	135	TRS	10.0 (4.0)	15 (5)	< 10
13	-	T. Emery Construction Company Ltd.	136	TRS	13.5 (5.5)	20 (6)	< 10 overgrown, partially water filled
14	-	Seal-on Paving Ltd.	139	TRS	19.0 (7.7)	20-30 (6-9)	< 20
15	-	J.H. Smith	139,140	TRS	5.4 (2.2)	15-30 (5-9)	< 20

TABLE 2. SAND AND GRAVEL PITS, RALEIGH AND HARWICH TOWNSHIPS.

1 NO.	2 MTO NO.	3 OWNER/OPERATOR	4 LOT	5 CONC.	6 LICENCED AREAS Acres (Hectares)	7 FACE HEIGHT Feet (Metres)	8 % GRAVEL
16	-	Township of Chatham	141	TRS	5.9 (2.4)	10–25 (3–8)	< 10
					102.7 (41.6)		
Total Licenced Area in Raleigh and Harwich Townships:					582.0 (235.5)		
UNLICENCED PITS*							
Harwich Township							
17	-	Unknown	19	11		4 (1) (above water)	variable
18	-	Unknown	13	11		5 (2)	water filled
19	-	Unknown	27	1 WCR		3 (1)	overgrown
20	R5–14	Vogler	7	Townline Range		12–15 (4–5)	< 20 overgrown, partially water filled
21	R5–13	Verstrate	7	6		12 (4)	15 overgrown, water filled
22	R5–09	Alfons Van Loock	16	6		15–25 (5–8)	20 overgrown, water filled
23	-	Unknown	12	1 WCR		3 (1)	-
24	C8–6	Kent County	10	2 WCR		10–15 (3–5)	< 20 overgrown
25	C8–17	McGuigan	10	2 WCR		15 (5)	< 20 overgrown
26	C6–42	R.Cartwright	9	4 WCR		10–15 (3–5)	< 20 overgrown, water filled
27	-	Unknown	9	4 WCR		25 (8)	< 20 overgrown, water filled
28	-	Unknown	9	4 WCR		15–25 (5–8)	backfilled
Raleigh Township							
29	C8–7	Kent County	129	2 TRS		20–30 (1–9)	overgrown, rehabilitated
30	C8–2	H.Beck	129	2 TRS		15 (5)	overgrown, water filled
31	C8–45	Peel Construction	130	2 TRS		10–15 (3–5)	overgrown

TABLE 2. SAND AND GRAVEL PITS, RALEIGH AND HARWICH TOWNSHIPS.

1 NO.	2 MTO NO.	3 OWNER/OPERATOR	4 LOT	5 CONC.	6 LICENCED AREAS Acres (Hectares)	7 FACE HEIGHT Feet (Metres)	8 % GRAVEL
32	C8-12	Doey	130,131	2 TRS		20-30 (6-9)	overgrown, water filled
33	C8-46	R.Leque	133	TRS		30-45 (9-14)	overgrown
34	C8-10	Sterling	133	TRS		20-40 (6-12)	overgrown, water filled
35	C8-22	Delanghe	134	TRS		30-50 (9-15)	< 15 overgrown, water filled
36	C8-20	J.Smith M. Delanghe	135	TRS		20-30 (6-9)	< 20 overgrown
37	C8-11	Harris	135	TRS		25-30 (8-9)	20-30 overgrown
38	-	Brisco	141	TRS		15-30 (5-9)	< 20 partially overgrown
39	-	Unknown	141	TRS		10-25 (3-8)	10-20 overgrown
40	-	Unknown	12	4		2-5 (1-2)	clay source

* *Abandoned pits, or wayside pits operating on demand under authority of a permit.*

TABLE 3. SELECTED SAND AND GRAVEL RESOURCE AREAS, RALEIGH AND HARWICH TOWNSHIPS.

1 DEPOSIT NO.	2 UNLICENCED AREA Acres (Hectares)	3 CULTURAL SETBACKS Acres (Hectares)	4 EXTRACTED AREA Acres (Hectares)	5 AVAILABLE AREA Acres (Hectares)	6 ESTIMATED DEPOSIT THICKNESS Feet (Metres)	7 AVAILABLE AGGREGATE Millions of Tons (Tonnes)
1	770 (310)	125 (51)	0 (0)	650 (265)	50 (15)	96 (87)
2	7500 (3050)	2240 (910)	260 (105)	5000 (2020)	30 (9)	560 (510)
TOTAL FOR STUDY AREA:	8300 (3350)	2360 (960)	260 (105)	5600 (2270)		660 (600)

TABLE 4. TOTAL IDENTIFIED BEDROCK RESOURCES, RALEIGH AND HARWICH TOWNSHIPS.

1 DRIFT THICKNESS Feet (Metres)	2 FORMATION	3 ESTIMATED DEPOSIT THICKNESS Feet (Metres)	4 AREAL EXTENT Acres (Hectares)	5 ORIGINAL TONNAGE Millions of Ton (Tonnes)
25–50 (8–15)	Kettle Point Formation	60 (18)	590 (239)	113 (102)

TABLE 5. QUARRIES, RALEIGH AND HARWICH TOWNSHIPS.

1 NO.	2 MTO NO.	3 OWNER/ OPERATOR	4 LOT	5 CONC.	6 LICENCED AREA Acres (Hectares)	7 FACE HEIGHT Feet (Metres)

- NONE -

TABLE 6. SELECTED BEDROCK RESOURCE AREAS, RALEIGH AND HARWICH TOWNSHIPS.

1 DEPOSIT NO.	2 DEPTH OF OVERBURDEN Feet (Metres)	3 UNLICENCED AREA Acres (Hectares)	4 CULTURAL SETBACKS Acres (Hectares)	5 EXTRACTED AREA Acres (Hectares)	6 AVAILABLE AREA Acres (Hectares)	7 ESTIMATED WORKABLE THICKNESS Feet (Metres)	8 AVAILABLE RESOURCES Millions of Tons (Tonnes)

- NONE -

TABLE 7. SUMMARY OF TEST HOLE DATA, RALEIGH AND HARWICH TOWNSHIPS.*

Test Hole Number: RH-TH-1

Location: Lots 16 & 17, Conc. 13 LES, Harwich Township (test hole completed in pit no. 2)

Elevation: Approximately 600 feet (183 m) asl

Source: Quaternary Geology Subsection, Engineering and Terrain Geology Section, Ontario Geological Survey

Depth feet (metres)	Description
0–20 (0–6)	clay till
20–23 (6–7)	coarse gravel terminated hole at 23 feet (7 m)

Test Hole Number: RH-TH-2

Location: Lots 16 & 17, Conc. 13 LES, Harwich Township (test hole completed in pit no. 2)

Elevation: Approximately 600 feet (183 m) asl

Source: Quaternary Geology Subsection Engineering and Terrain Geology Section Ontario Geological Survey

Depth feet (metres)	Description
0–21 (0–6)	clay till
21–23 (6–7)	coarse cobbly gravel terminated hole at 23 feet (7 m)

Test Hole Number: RH-TH-3

Location: Lot 15, Conc. 13 LES, Harwich Township

Elevation: Approximately 600 feet (183 m) asl

Source: Quaternary Geology Subsection Engineering and Terrain Geology Section Ontario Geological Survey

Depth feet (metres)	Description
0–5 (0–2)	no sample
5–10 (2–3)	gravelly coarse sand
10–15 (3–5)	fine sand
15–20 (5–6)	massive silty sand till
20–25 (6–8)	fine sand
25–30 (8–9)	fine sand with occasional gravel
30–35 (9–11)	fine sand
35–40 (11–12)	fine sand with silt and few pebbles
40–45 (12–14)	coarse clean sand
45–55 (14–17)	no recovery terminated hole at 55 feet (17 m)

Test Hole Number: RH-TH-4

Location: Lot 15, Conc. 13 LES, Harwich Township

Elevation: Approximately 600 feet (183 m) asl

Source: Quaternary Geology Subsection Engineering and Terrain Geology Section Ontario Geological Survey

Depth feet (metres)	Description
0–5 (0–2)	massive clayey silt till in reddish pockets
5–10 (2–3)	laminated waterlain till with red- and olive-coloured chips more consolidated than above
10–15 (3–5)	highly consolidated sandy silt till
15–25 (5–8)	clean medium sand
25–30 (8–9)	medium sand
30–35 (9–11)	gravelly sand
35–55 (11–17)	gravelly coarse sand minor clay contamination terminated hole at 63 feet (19 m)

TABLE 7. SUMMARY OF TEST HOLE DATA, RALEIGH AND HARWICH TOWNSHIPS.*

Test Hole Number: RH–TH–5
Location: Lot 7, Conc. A, Raleigh Township
Elevation: 595.70 feet (181.57 m) asl
Source: Johnson (1985).

Depth feet (metres)	Description
0–87.27 (0–26.6)	overburden
87.27–175.62 (26.6–53.53)	Kettle Point Formation
175.62–179.53 (53.53–54.72)	Ipperwash Formation
179.53–209.17 (54.72–63.76)	Widder Formation
209.17 (63.76)	end of core

Test Hole Number: RH–TH–6
Location: Lot 3, Conc. 9, Raleigh Township
Elevation: Approximately 607 feet (185 m) asl
Source: From files of Petroleum Resources Section, MNR

Depth feet (metres)	Description
0–120 (0–37)	drift
120–181 (37–55)	Kettle Point Formation
181–322 (55–98)	Hamilton Group
322–488 (98–149)	Dundee Formation
488–730 (149–223)	Detroit River Group
	test hole continued to 3735 feet (1138 m), abandoned

Test Hole Number: RH–TH–7
Location: Lot 2, Conc. 12, Raleigh Township
Elevation: Approximately 625 feet (191 m) asl
Source: From files of Petroleum Resources Section, MNR

Depth feet (metres)	Description
0–160 (0–49)	drift
160–240 (49–73)	Kettle Point Formation
240–306 (73–93)	Hamilton Group
	test hole continued to 1377 feet (420 m), abandoned

Test Hole Number: RH–TH–8
Location: Lot 162, Conc. TRS, Raleigh Township
Elevation: Approximately 641 feet (195 m) asl
Source: From files of Petroleum Resources Section, MNR

Depth feet (metres)	Description
0–146 (0–45)	drift
146–325 (45–99)	Hamilton Group
325–464 (99–141)	Dundee Formation
	test hole continued to 1411.5 feet (430.2 m), abandoned

Test Hole Number: RH–TH–9
Location: Lot 153, Conc. TRS, Raleigh Township
Elevation: Approximately 644 feet (196 m) asl
Source: From files of Petroleum Resources Section, MNR

Depth feet (metres)	Description
0–170 (0–52)	drift
170–210 (52–64)	Kettle Point Formation
210–380 (64–116)	Hamilton
380–400 (116–122)	Dundee Formation
	test hole terminated at 400 feet (122 m)

Test Hole Number: RH–TH–10
Location: Lot 16, Conc. 15, Raleigh Township
Elevation: Approximately 643 feet (196 m) asl
Source: From files of Petroleum Resources Section, MNR

Depth feet (metres)	Description
0–200 (0–61)	drift
	test hole continued to 1647 feet (502 m), abandoned

Test Hole Number: RH–TH–11
Location: Lot 18, Conc. 16, Raleigh Township
Elevation: Approximately 647 feet (197 m) asl
Source: From files of Petroleum Resources Section, MNR

Depth feet (metres)	Description
0–200 (0–61)	drift
200–303 (61–92)	Hamilton Group
303–315 (92–96)	Dundee Formation
	test hole terminated at 315 feet (96 m)

TABLE 7. SUMMARY OF TEST HOLE DATA, RALEIGH AND HARWICH TOWNSHIPS.*

Test Hole Number: RH–TH–12
Location: Lot 24, Conc. 1 LES, Raleigh Township
Elevation: 585.17 feet (178.36 m) asl
Source: Johnson (1985).

Depth feet (metres)	Description
0–105.51 (0–32.16)	overburden
105.51–105.61 (32.16–32.19)	Igneous boulder
105.61–163.68 (32.19–49.89)	Kettle Point Formation
163.68–190.52 (49.89–58.07)	Widder Formation
190.52 (58.07)	end of core

Test Hole Number: RH–TH–13
Location: Lot. 18, Conc. 1 RTS, Harwich Township
Elevation: Approximately 594 feet (181 m) asl
Source: From files of Petroleum Resources Section, MNR

Depth feet (metres)	Description
0–35 (0–11)	drift
35–95 (11–29)	Kettle Point Formation
95–405 (29–123)	Hamilton Group
405–540 (123–165)	Dundee Formation test hole abandoned at 540 feet (165 m)

Test Hole Number: RH–TH–14
Location: Lot 25, Conc. 1 ECR, Tract 1, Harwich Township
Elevation: 593.11 feet (180.78 m) asl
Source: Johnson et al. (1985).

Depth feet (metres)	Description
0–67.25 (0–20.50)	overburden, glacial material
67.25–148.98 (20.50–45.41)	Kettle Point Formation
148.98–176.97 (45.41–53.94)	Ipperwash Formation
176.97–226.97 (53.94–69.18)	Widder Formation
226.97–231.72 (69.18–70.63)	Hungry Hollow Formation
231.72–297.47 (70.63–90.67)	Arkona Formation
297.47–321.00 (90.67–97.84)	Rockport Quarry Formation
321.00–350.88 (97.84–106.95)	Bell Formation
350.88–495.57 (106.95–151.05)	Dundee Formation
495.57–600.98 (151.05–183.18)	Detroit River Group Lucas Formation
600.98–630.15 (183.18–192.07)	Detroit River Group Amherstburg Formation
630.15–857.91 (192.07–261.49)	Bois Blanc Formation Springvale Member
857.91–948.49 (261.49–289.10)	Bass Island Formation
948.49–1161.98 (289.10–354.17)	Salina Formation
1161.98–1653.97 (354.17–504.13)	Guelph Formation
1653.97–1892.98 (504.13–567.98)	Lockport Formation, Goat Island and Gasport Member
1892.98–1922.47 (576.98–585.97)	Rochester Formation
1922.47–1928.97 (585.97–587.95)	Reynales Formation
1928.97–2023.98 (587.95–616.91)	Cabot Head Formation
2023.98–2090.98 (616.91–637.33)	Manitoulin Formation
2090.98–2411.91 (637.33–735.15)	Queenston Formation
2411.91–2817.98 (735.15–858.92)	Georgian Bay Formation
2817.98–2950.98 (858.92–899.46)	Blue Mountain Formation
2950.98–3065.22 (899.46–934.28)	Cobourg Formation
3065.22–3208.99 (934.28–978.10)	Sherman Falls Formation
3208.99–3375.72 (978.10–1028.92)	Kirkland Formation
3375.72–3477.99 (1028.92–1060.09)	Coboconk Formation
3477.99–3837.37 (1060.09–1169.63)	Gull River Formation
3837.37–3854.99 (1169.63–1175.00)	Shadow Lake Formation
3854.99–3873.98 (1175.00–1180.79)	Eau Claire Formation
3873.98 (1180.79)	end of core

TABLE 7. SUMMARY OF TEST HOLE DATA, RALEIGH AND HARWICH TOWNSHIPS.*

Test Hole Number: RH–TH–15

Location: Lot 19, Conc. 11 & 12, Harwich Township

Elevation: 611.71 feet (186.45 m) asl

Source: Johnson (1985).

Depth feet (metres)	Description
0–35.83 (0–10.92)	Overburden, boulders mixed limestone/ metasediment/pink granite
35.83–196.19 (10.92–59.80)	Kettle Point Formation
196.19–240.85 (59.80–73.41)	Ipperwash Formation
240.85 (73.41)	end of core

**Test holes RH–TH–1 to RH–TH–4 are identified on Map 1, and RH–TH–5 to RH–TH–15 are identified on Map 3.*

TABLE 8. SUMMARY OF GEOPHYSICS DATA, RALEIGH AND HARWICH TOWNSHIPS.

Line Number: RH–GT–1

Line Direction: North–south

Method: Hammer Seismic

Location: Lot 129, Conc. TRS, Raleigh Township (completed on floor of pit no. 10)

Elevation: Approximately 675 feet (206 m) asl

Sesimic data:

Number of layers: 2

Layer Velocities: V_1 = 1150 ft/sec (351 m/s)
V_2 = 5000 ft/sec (1524 m/s)

Layer Thickness: 13 feet (4 m)

Interpretation: Layer 1: Approximately 13 feet (4 m) of spit gravel and gravelly sand.

Layer 2: Till possibly encountered and velocities increased to 5000 ft/sec (1524 m/s) (water well data in the immediate area indicates the presence of underlying clay).

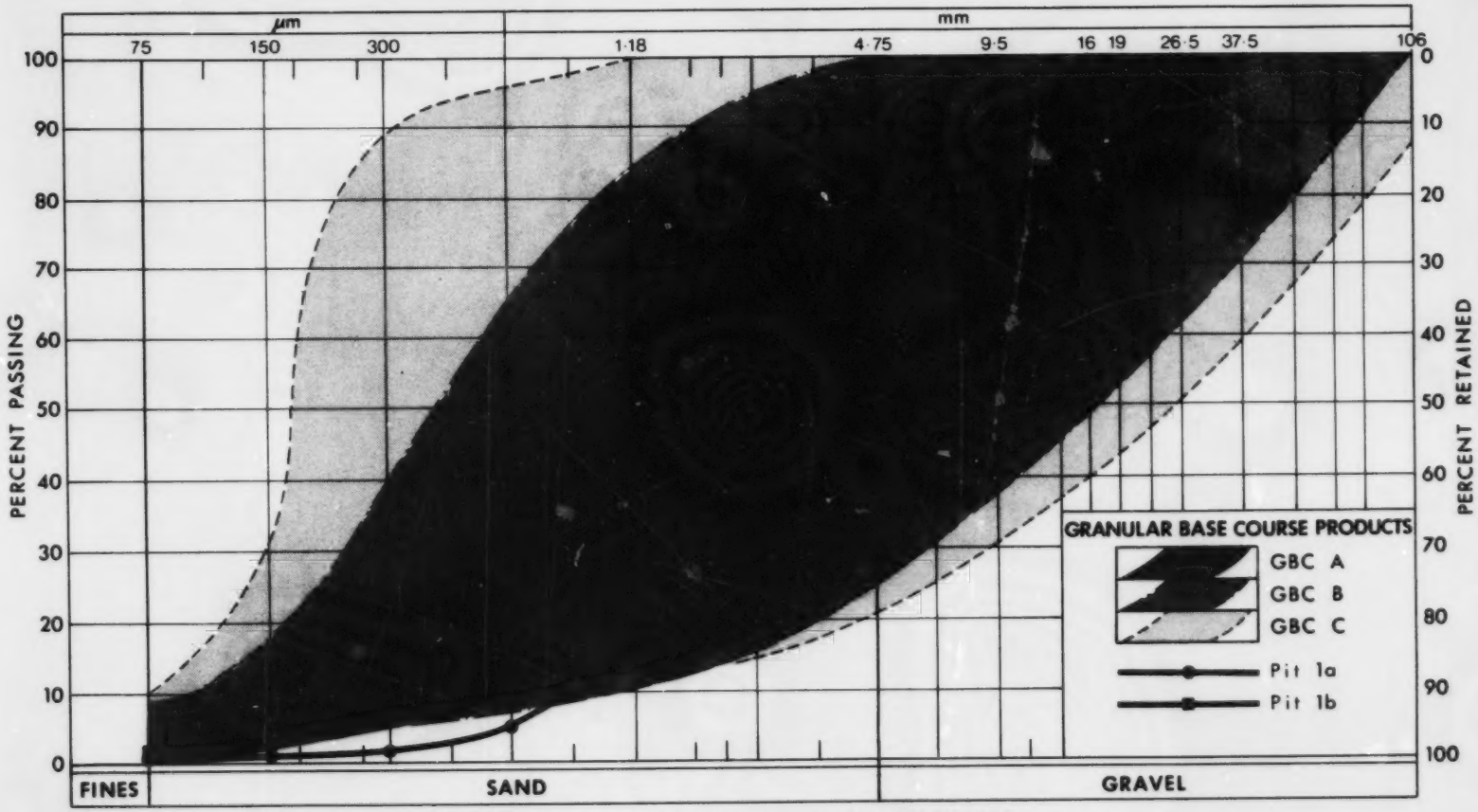


FIGURE 2a. AGGREGATE GRADING CURVES, RALEIGH AND HARWICH TOWNSHIPS.

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M T O Form 1010, 1980).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

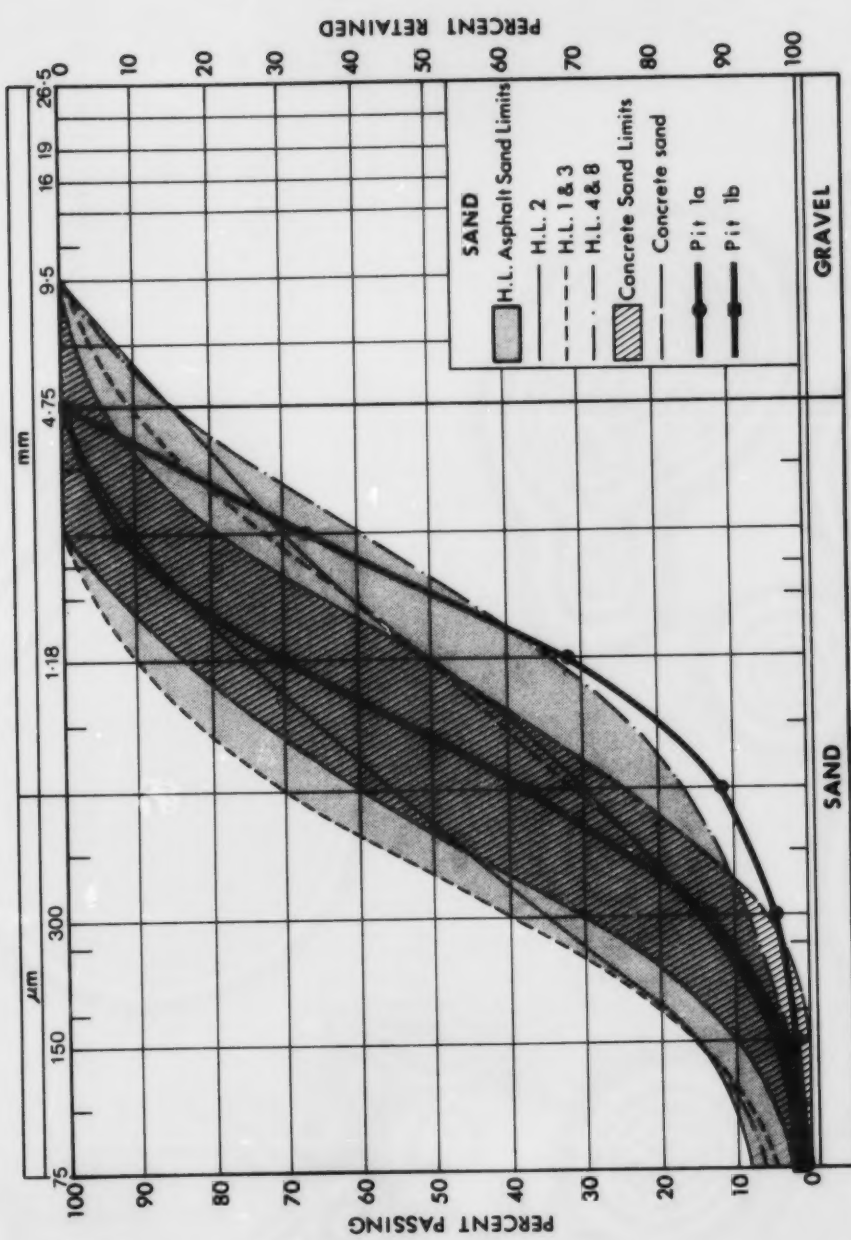


FIGURE 2b. AGGREGATE GRADING CURVES, RALEIGH AND HARWICH TOWNSHIPS.

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.O. Forms 1002, 1979 and 1003, 1981).

NOTE: Information portrayed by grading curves refers strictly to a specific sample at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

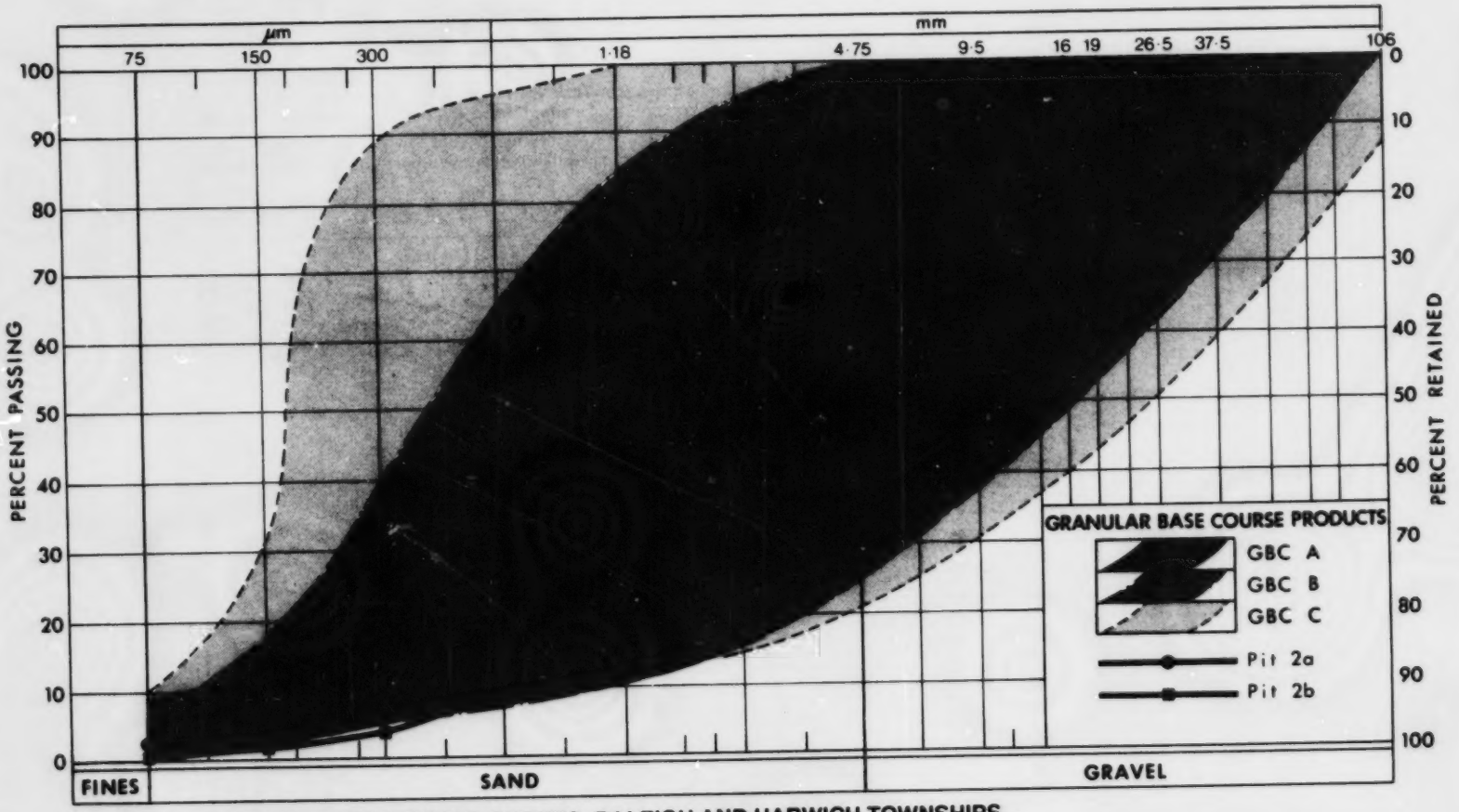


FIGURE 3a. AGGREGATE GRADING CURVES, RALEIGH AND HARWICH TOWNSHIPS.

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M T O Form 1010, 1980).

NOTE:

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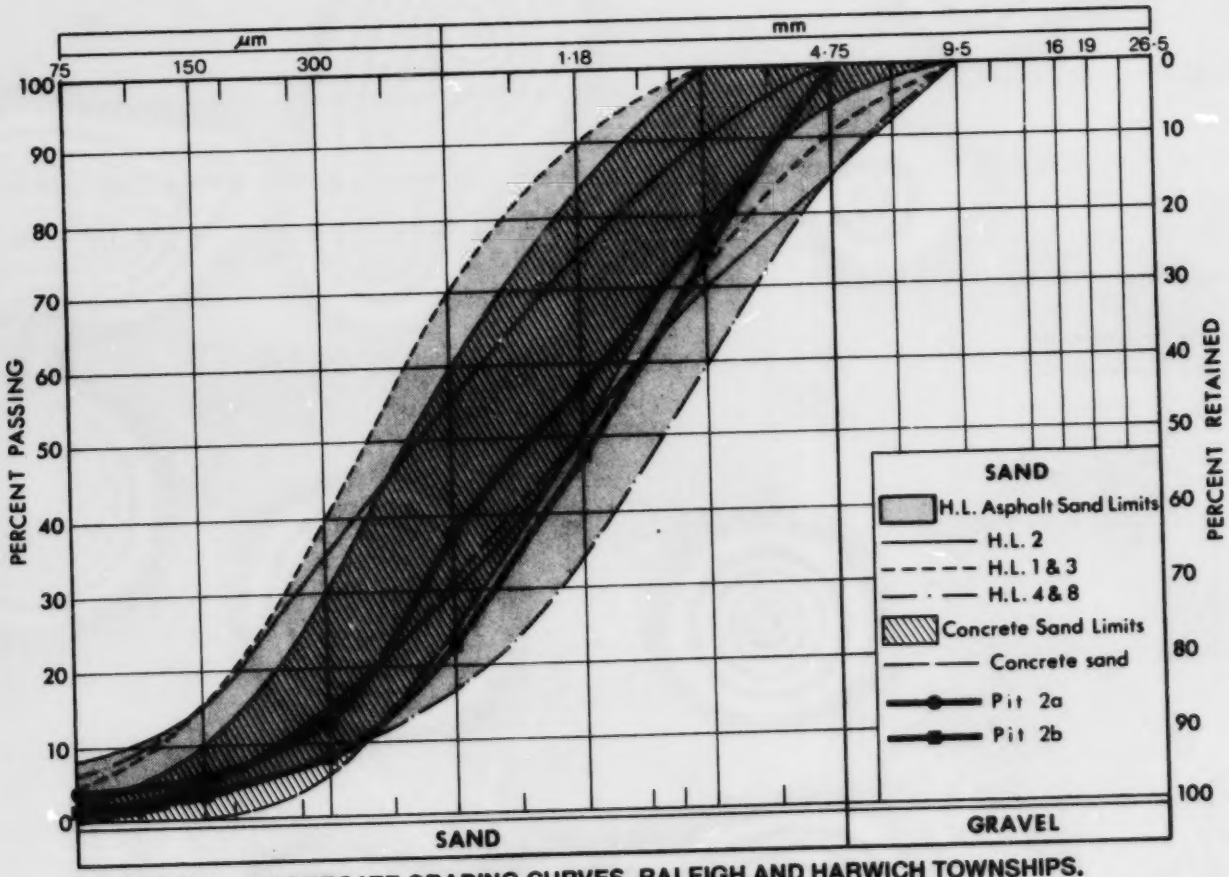

FIGURE 3b. AGGREGATE GRADING CURVES, RALEIGH AND HARWICH TOWNSHIPS.

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.O. Forms 1002, 1979 and 1003, 1981).

NOTE: Information portrayed by grading curves refers strictly to a specific sample at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

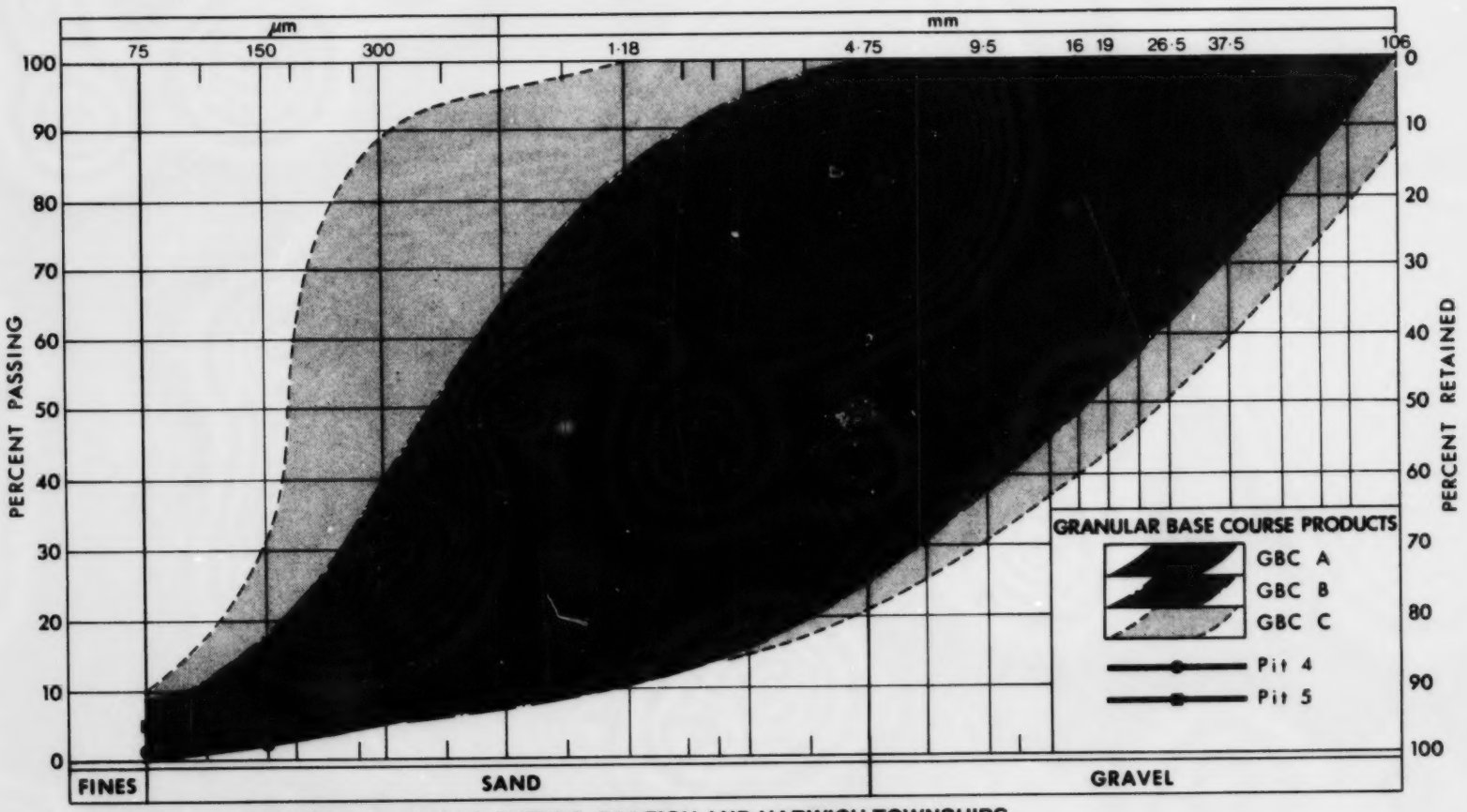

FIGURE 4a. AGGREGATE GRADING CURVES, RALEIGH AND HARWICH TOWNSHIPS.

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M T O Form 1010, 1980).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

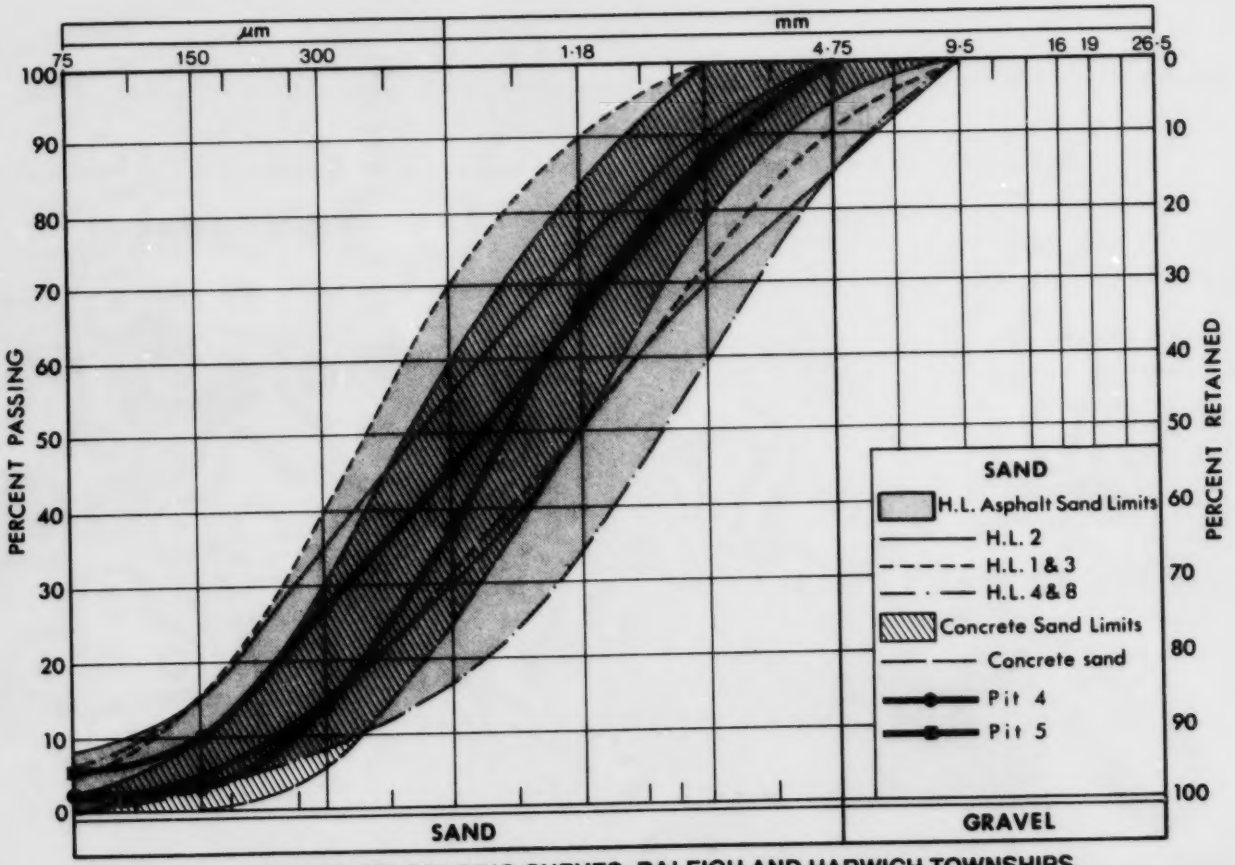

FIGURE 4b. AGGREGATE GRADING CURVES, RALEIGH AND HARWICH TOWNSHIPS.

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.O. Forms 1002, 1979 and 1003, 1981).

NOTE: Information portrayed by grading curves refers strictly to a specific sample at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

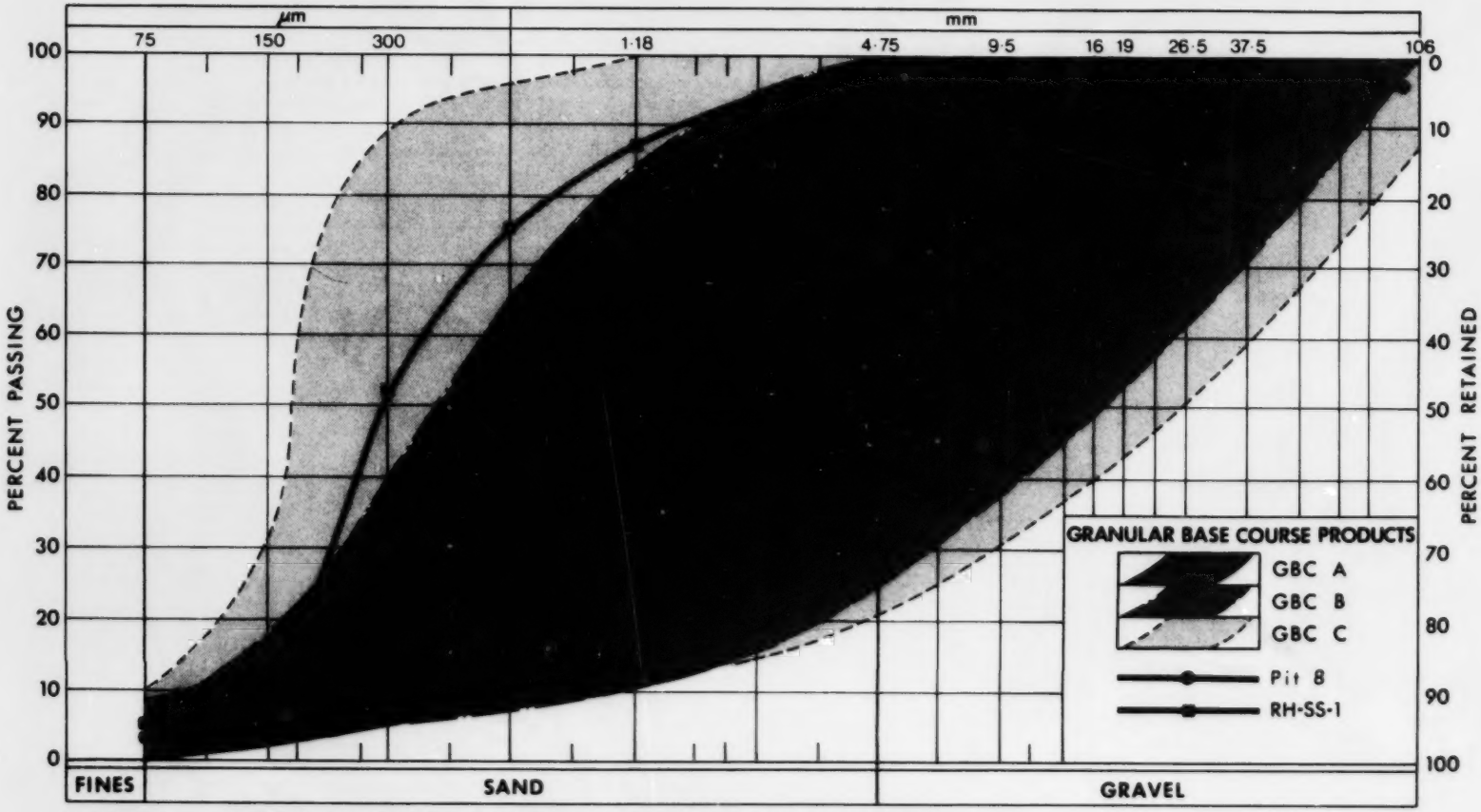

FIGURE 5a. AGGREGATE GRADING CURVES, RALEIGH AND HARWICH TOWNSHIPS.

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M T O Form 1010, 1980).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

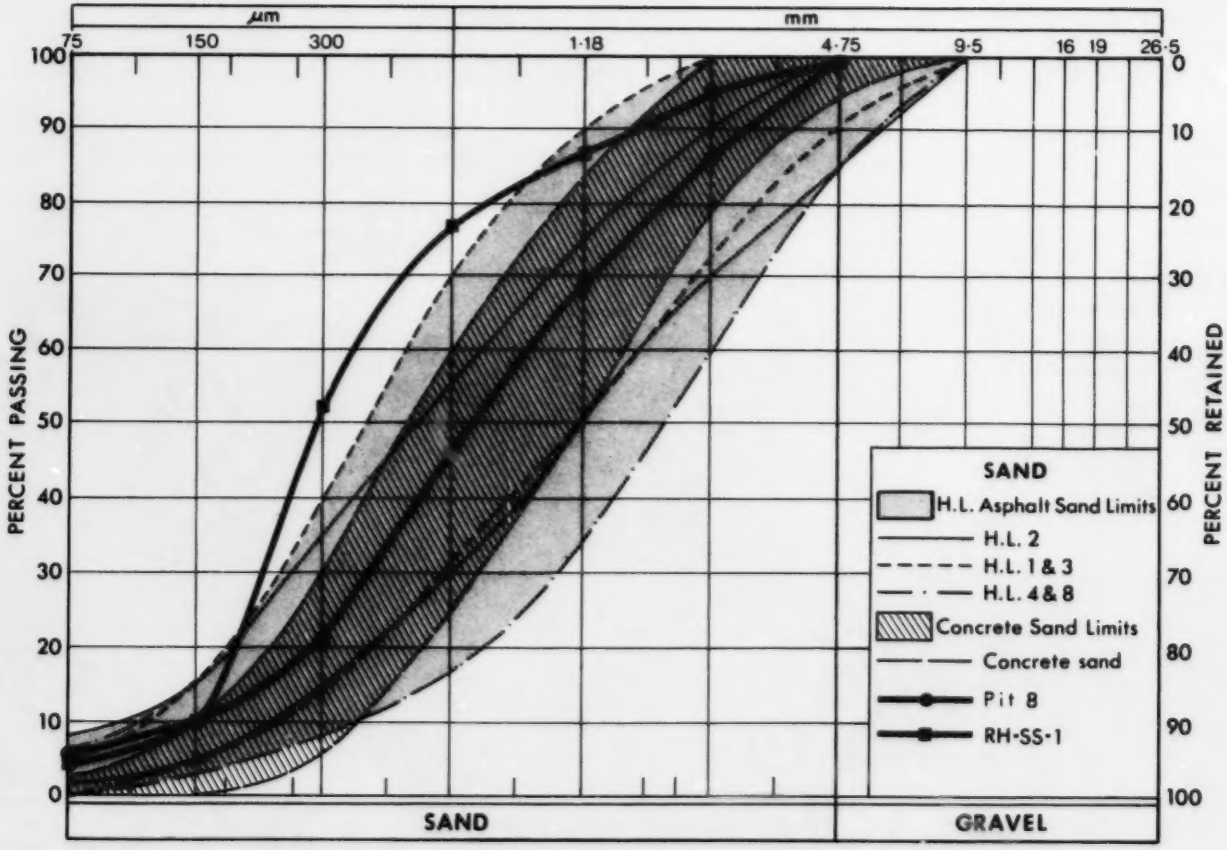

FIGURE 5b. AGGREGATE GRADING CURVES, RALEIGH AND HARWICH TOWNSHIPS.

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.O. Forms 1002, 1979 and 1003, 1981).

NOTE: Information portrayed by grading curves refers strictly to a specific sample at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

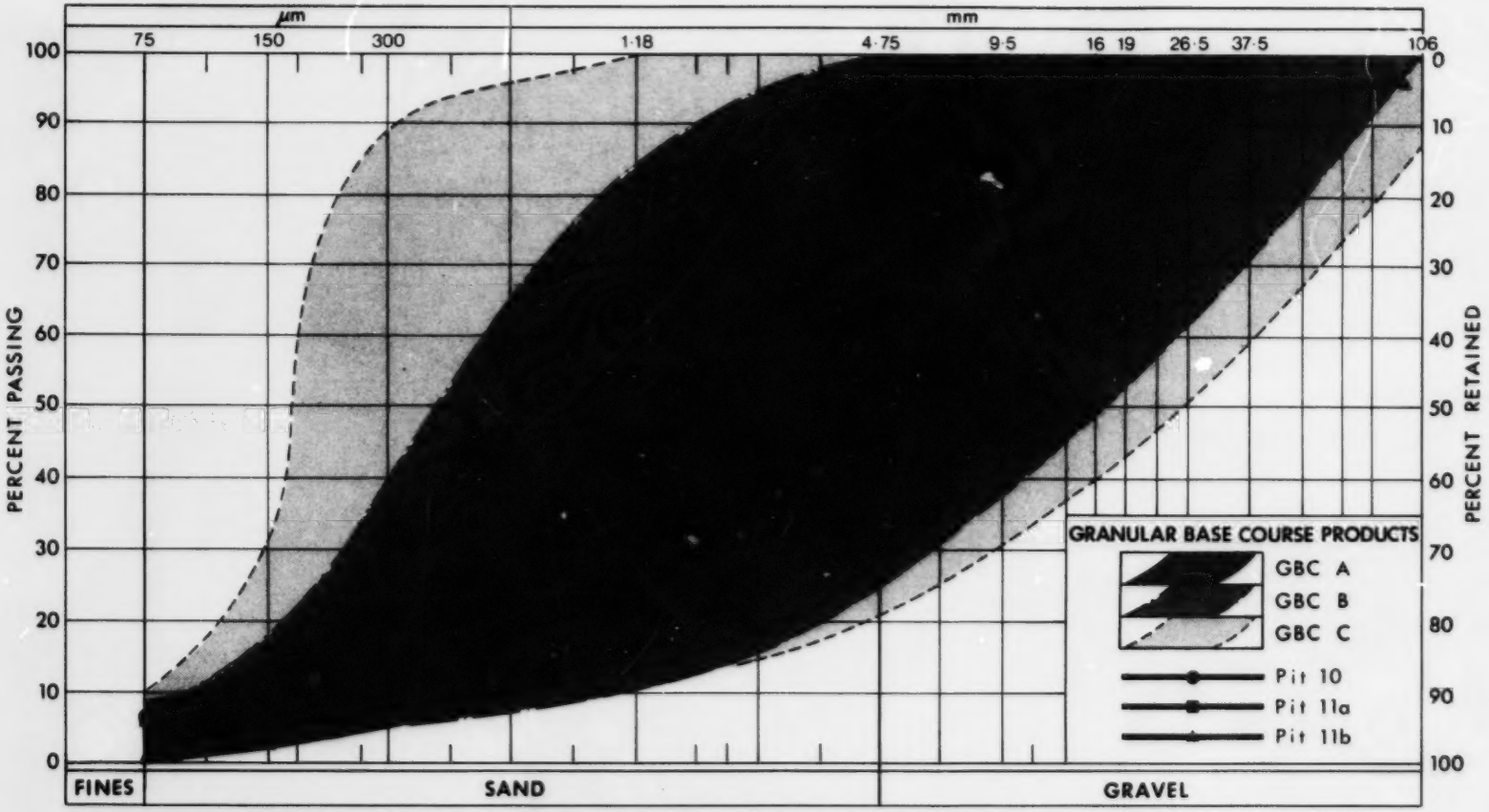

FIGURE 6a. AGGREGATE GRADING CURVES, RALEIGH AND HARWICH TOWNSHIPS.

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M T O Form 1010, 1980).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

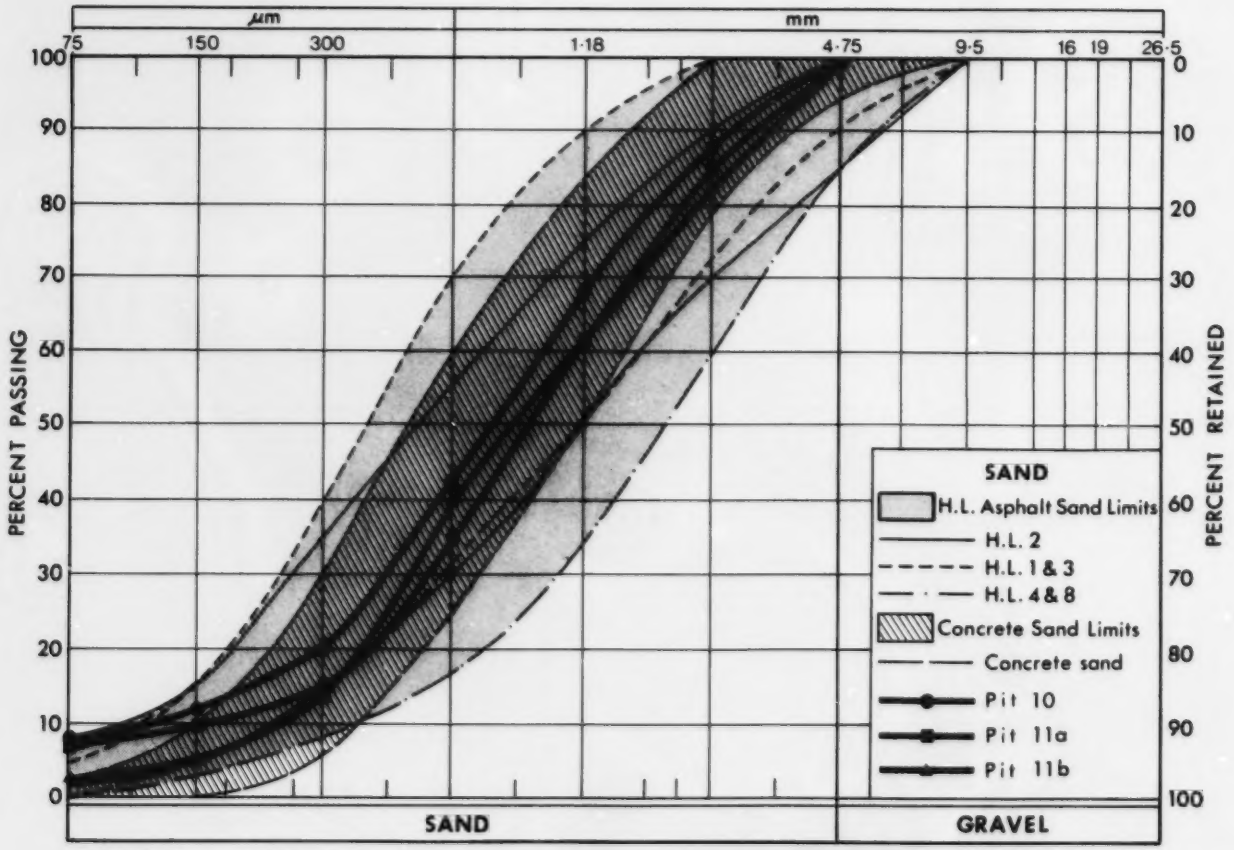

FIGURE 6b. AGGREGATE GRADING CURVES, RALEIGH AND HARWICH TOWNSHIPS.

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.O. Forms 1002, 1979 and 1003, 1981).

NOTE: Information portrayed by grading curves refers strictly to a specific sample at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

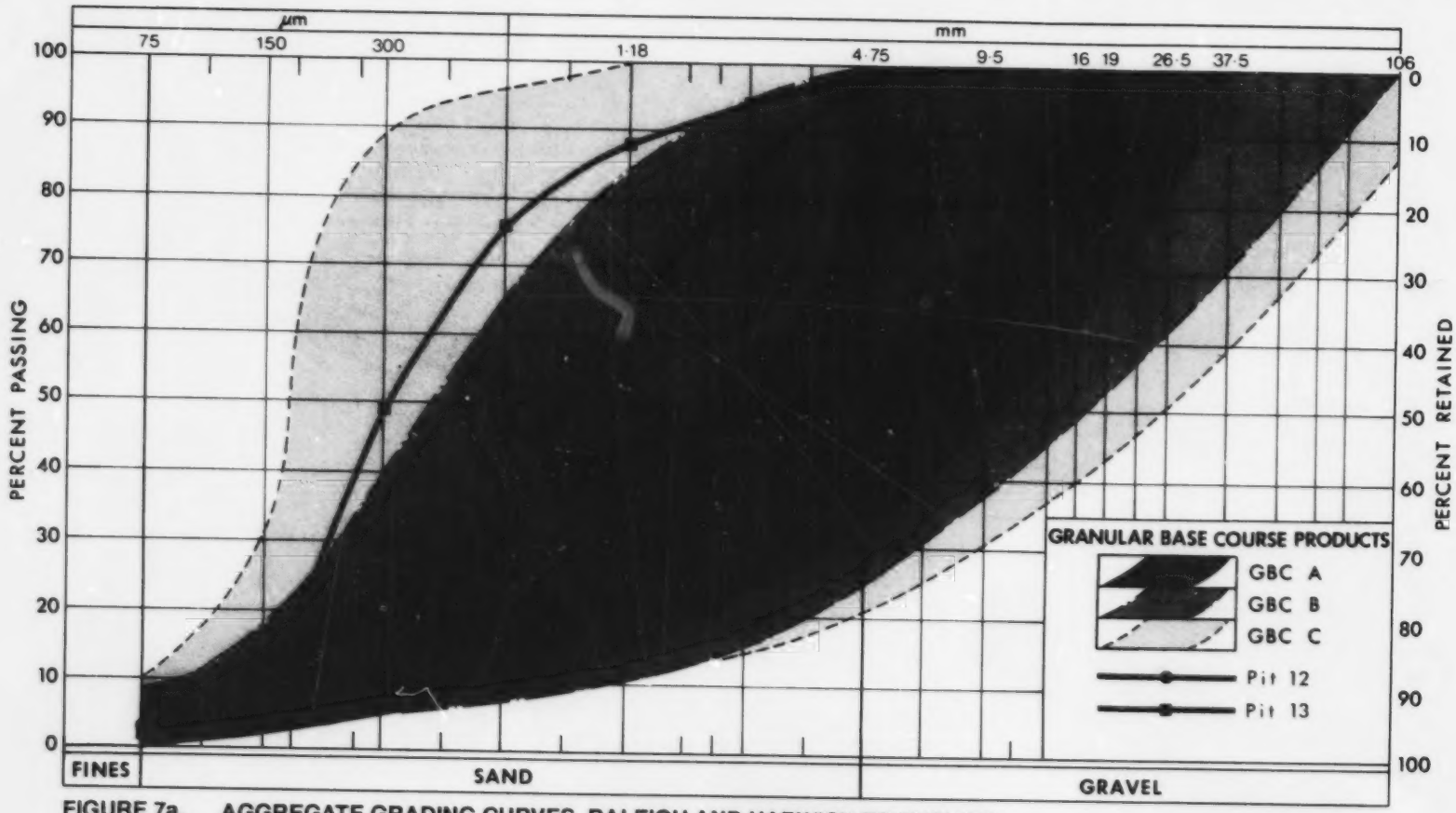

FIGURE 7a. AGGREGATE GRADING CURVES, RALEIGH AND HARWICH TOWNSHIPS.

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M T O Form 1010, 1980).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

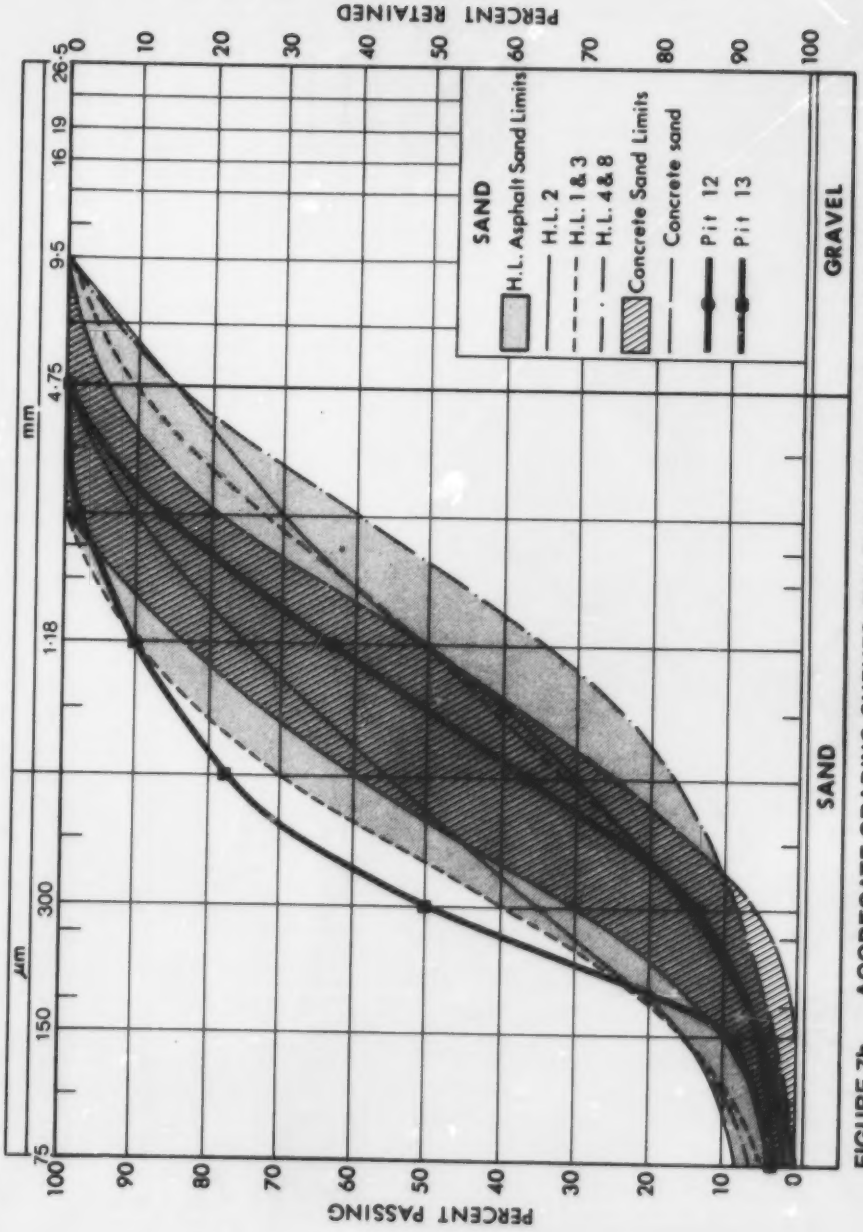

FIGURE 7b. AGGREGATE GRADING CURVES, RALEIGH AND HARWICH TOWNSHIPS.

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.O. Forms 1002, 1979 and 1003, 1981).

NOTE: Information portrayed by grading curves refers strictly to a specific sample at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

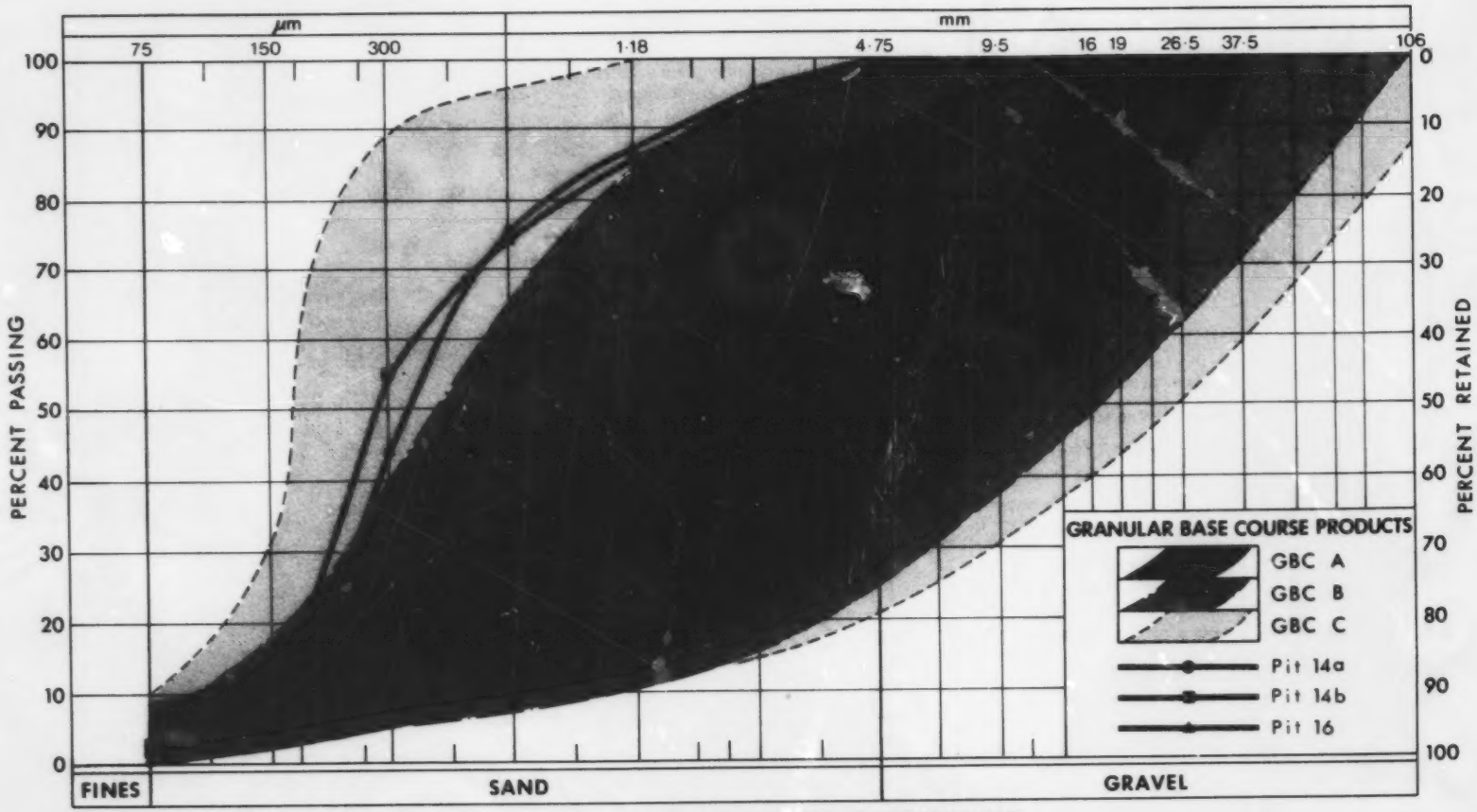

FIGURE 8a. AGGREGATE GRADING CURVES, RALEIGH AND HARWICH TOWNSHIPS.

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M T O Form 1010, 1980).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

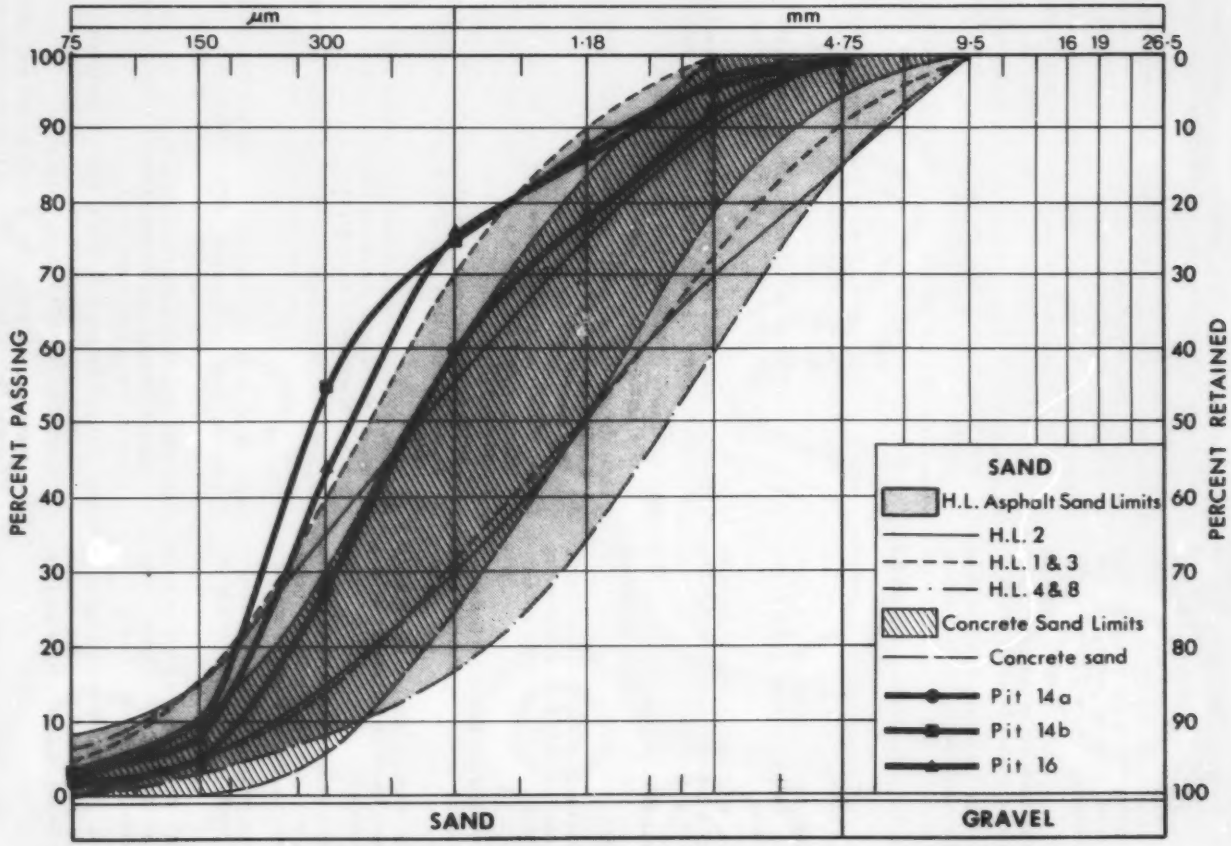

FIGURE 8b. AGGREGATE GRADING CURVES, RALEIGH AND HARWICH TOWNSHIPS.

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.O. Forms 1002, 1979 and 1003, 1981).

NOTE: Information portrayed by grading curves refers strictly to a specific sample at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

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Appendix B — Glossary

Abrasion resistance: Tests such as the Los Angeles abrasion test are used to measure the ability of aggregate to resist crushing and pulverizing under conditions similar to those encountered in processing and use. Measuring resistance is an important component in the evaluation of the quality and prospective uses of aggregate. Hard, durable material is preferred for road building.

Absorption capacity: Related to the porosity of the rock types of which an aggregate is composed. Porous rocks are subject to disintegration when absorbed liquids freeze and thaw, thus decreasing the strength of the aggregate.

Aggregate: Any hard, inert, construction material (sand, gravel, shells, slag, crushed stone or other mineral material) used for mixing in various-sized fragments with a cement or bituminous material to form concrete, mortar, etc., or used alone for road building or other construction. Synonyms include mineral aggregate and granular material.

Aggregate Abrasion Value: This test directly measures the resistance of aggregate to abrasion with silica sand and a steel disk. The higher the value, the lower the resistance to abrasion. For high quality asphalt surface course uses, values of less than 6 are desirable.

Alkali-aggregate reaction: A chemical reaction between the alkalis of portland cement and certain minerals found in rocks used for aggregate. Alkali-aggregate reactions are undesirable because they can cause expansion and cracking of concrete. Although perfectly suitable for building stone and asphalt applications, alkali-reactive aggregates should be avoided for structural concrete uses.

Beneficiation: Beneficiation of aggregates is a process or combination of processes which improves the quality (physical properties) of a mineral aggregate and is not part of the normal processing for a particular use, such as routine crushing, screening, washing or classification. Heavy media separation, jigging, or application of special crushers (e.g., "cage mill") are usually considered processes of beneficiation.

Blending: Required in cases of extreme coarseness, fineness, or other irregularities in the gradation of unprocessed aggregate. Blending is done with approved sand-sized aggregate in order to satisfy the gradation requirements of the material.

Bulk Relative Density: An aggregate with low relative density is lighter in weight than one with a high relative density. Low relative density aggregates (less than about 2.5) are often non-durable for many aggregate uses.

Cambrian: The first period of the Paleozoic Era, thought to have covered the time between 570 and 500 million years ago. The Cambrian precedes the Ordovician Period.

Clast: An individual constituent, grain or fragment of a sediment or rock, produced by the mechanical weathering of larger rock mass. Synonyms include particle and fragment.

Crushable aggregate: Unprocessed gravel containing a minimum of 35% coarse aggregate larger than the No. 4 sieve (4.75 mm) as well as a minimum of 20% greater than the 26.5 mm sieve.

Deleterious lithology: A general term used to designate those rock types which are chemically or physically unsuited for use as construction or road-building aggregates. Such lithologies as chert, shale, siltstone and sandstone may deteriorate rapidly when exposed to traffic and other environmental conditions.

Devonian: A period of the Paleozoic Era thought to have covered the span of time between 395 and 345 million years ago, following the Silurian Period. Rocks formed in the Devonian Period are among the youngest found in Ontario.

Dolostone: A carbonate sedimentary rock consisting chiefly of the mineral dolomite and containing relatively little calcite (dolostone is also known as dolomite).

Drift: A general term for all unconsolidated rock debris transported from one place and deposited in another, distinguished from underlying bedrock. In North America, glacial activity has been the dominant mode of transport and deposition of drift. Synonyms include overburden and surficial deposit.

Drumlin: A low, smoothly rounded, elongated hill, mound, or ridge composed of glacial materials. These landforms were formed beneath an advancing ice sheet, and were shaped by its flow.

Eolian: Pertaining to the wind, especially with respect to landforms whose constituents were transported and deposited by wind activity. Sand dunes are an example of an eolian landform.

Fines: A general term used to describe the size fraction of an aggregate which passes (is finer than) the No. 200 mesh screen (0.075 mm). Also described informally as "dirt", these particles are in the silt and clay size range.

Glacial lobe: A tongue-like projection from the margin of the main mass of an ice cap or ice sheet. During the Pleistocene Epoch several lobes of the Laurentide continental ice sheet occupied the Great Lakes basins. These lobes advanced then melted back numerous times during the Pleistocene, producing the complex arrangement of glacial material and landforms found in southern Ontario.

Gradation: The proportion of material of each particle size, or the frequency distribution of the various sizes which constitute a sediment. The strength, durability, permeability and stability of an aggregate depend to a great extent on its gradation. The size limits for different particles are as follows:

Boulder	more than 200 mm
Cobbles	75-200 mm
Coarse Gravel	26.5-75 mm
Fine Gravel	4.75-26.5 mm
Coarse Sand	2-4.75 mm
Medium Sand	0.425-2 mm
Fine Sand	0.075-0.425 mm
Silt, Clay	less than 0.075 mm

Granular base course: Components of the pavement structure of a road, which are placed on the subgrade and are designed to provide strength, stability and drainage, as well as support for surfacing materials. Several types have been defined: Granular Base Course A consists of crushed and processed aggregate and has relatively stringent quality standards in comparison to Granular Base Course B and C which are usually pit-run or other unprocessed aggregate.

Hot-laid (or asphaltic) aggregate: Bituminous, cemented aggregates used in the construction of pavements either as surface or bearing course (HL 1, 3 and 4), or as binder course (HL 2 and 8) used to bind the surface course to the underlying granular base course.

Lithology: The description of rocks on the basis of such characteristics as colour, structure, mineralogic composition and grain size. Generally, the description of the physical character of a rock.

Los Angeles Abrasion and Impact Test: This test measures the resistance to abrasion and the impact strength of aggregate. This gives an idea of the breakdown that can be expected to occur when an aggregate is stockpiled, transported, and placed. Values less than about 35% indicate potentially satisfactory performance for most concrete and asphalt uses. Values of more than 45% indicate that the aggregate may be susceptible to excessive breakdown during handling and placing.

Magnesium sulphate soundness test: This test is designed to simulate the action of freezing and thawing on aggregates. Those aggregates which are susceptible to freezing and thawing will usually break down and give high losses in this test. Values greater than about 12 to 15% indicate potential problems for concrete and asphalt coarse aggregate.

Meltwater channel: A drainage way, often terraced, produced by water flowing away from a melting glacier margin.

Ordovician: An early period of the Paleozoic Era thought to have covered the span of time between 500 and 435 million years ago.

Paleozoic era: One of the major divisions of the geologic time scale thought to have covered the time between 570 and 230 million years ago, the Paleozoic Era (or Ancient Life Era) is subdivided into six geologic periods, of which only four (Cambrian, Ordovician, Silurian and Devonian) can be recognized in southern Ontario.

Petrographic examination: Individual aggregate particles in a sample are divided into categories good, fair, poor, and deleterious, based on their rock type (petrography) and knowledge of past field performance. A petrographic number (PN) is calculated. The higher the PN, the lower the quality of the aggregate.

Pleistocene: An epoch of the recent geological past including the time from approximately 2 million years ago to 7000 years ago. Much of the Pleistocene was characterized by extensive glacial activity and is popularly referred to as the "Great Ice Age".

Polished Stone Value: This test measures the frictional properties of aggregates after 6 hours of abrasion and polishing with an emery abasive. The higher the PSV, the higher the frictional properties of the aggregate. Values less than 45 indicate marginal frictional properties, while values greater than 55 indicate excellent frictional properties.

Possible resource: Reserve estimates based largely on broad knowledge of the geological character of the deposit and for which there are few, if any, samples or measurements. The estimates are based on assumed continuity or repetition for which there are reasonable geological indications.

Precambrian: The earliest geological period extending from the consolidation of the earth's crust to the beginning of the Cambrian.

Shale: A fine-grained, sedimentary rock formed by the consolidation of clay, silt or mud and characterized by well developed bedding planes, along which the rock breaks readily into thin layers. The term shale is also commonly used for fissile claystone, siltstone and mudstone.

Silurian: An early period of the Palezoic Era thought to have covered the time between 435 and 395 million years ago. The Silurian follows the Ordovician Period and precedes the Devonian Period.

Soundness: The ability of the components of an aggregate to withstand the effects of various weathering processes and agents. Unsound lithologies are subject to disintegration caused by the expansion of absorbed solutions. This may seriously impair the performance of road-building and construction aggregates.

Till: Unsorted and unstratified rock debris, deposited directly by glaciers, and ranging in size from clay to large boulders.

Wisconsinan: Pertaining to the last glacial period of the Pleistocene Epoch in North America. The Wisconsinan began approximately 100 000 years ago and ended approximately 7000 years ago. The glacial deposits and landforms of southern Ontario are predominantly the result of glacial activity during the Wisconsinan Stage.

Appendix C — Geology of Sand and Gravel Deposits

The type, distribution, and extent of sand and gravel deposits in southern Ontario are the result of extensive glacial and glacially influenced activity in Wisconsinan time during the Pleistocene Epoch, approximately 100 000 to 7000 years ago. The deposit types reflect the different depositional environments that existed during the melting and retreat of the continental ice masses, and can readily be differentiated on the basis of their morphology, structure, and texture. The deposit types are described below.

GLACIOFLUVIAL DEPOSITS

These deposits can be divided into two broad categories: those that were formed in contact with (or in close proximity to) glacial ice, and those that were deposited by meltwaters carrying materials beyond the ice margin.

Ice-Contact Terraces (ICT): These are glaciofluvial features deposited between the glacial margin and a confining topographic high, such as the side of a valley. The structure of the deposits may be similar to that of outwash deposits, but in most cases the sorting and grading of the material is more variable and the bedding is discontinuous because of extensive slumping. The probability of locating large amounts of crushable aggregate is moderate, and extraction may be expensive because of the variability of the deposits both in terms of quality and grain size distribution.

Kames (K): Kames are defined as mounds of poorly sorted sand and gravel deposited by meltwater in depressions or fissures on the ice surface or at its margin. During glacial retreat, the melting of supporting ice causes collapse of the deposits, producing internal structures characterized by bedding discontinuities. The deposits consist mainly of irregularly bedded and cross-bedded, poorly sorted sand and gravel. The present forms of the deposits include single mounds, linear ridges (crevasse fillings) or complex groups of landforms. The latter are occasionally described as "undifferentiated ice-contact stratified drift" (IC) when detailed subsurface information is unavailable. Since kames commonly contain large amounts of fine-grained material and are characterized by considerable variability, there is generally a low to moderate probability of discovering large amounts of good quality, crushable aggregate. Extractive problems encountered in these deposits are mainly the excessive variability of the aggregate and the rare presence of excess fines (silt- and clay-sized particles).

Eskers (E): Eskers are narrow, sinuous ridges of sand and gravel deposited by meltwaters flowing in tunnels within or at the base of glaciers, or in channels on the ice surface. Eskers vary greatly in size. Many, though not all eskers, consist of a central core of poorly sorted and stratified gravel characterized by a wide range in grain size. The core material is often draped on its flanks by better sorted and stratified gravel. The deposits have a high probability of containing a large proportion of crushable aggregate, and since they are generally built above the surrounding ground surface, are convenient extraction sites. For these reasons esker deposits have been traditional aggregate sources throughout Ontario, and are significant components of the total resources of many areas.

Some planning constraints and opportunities are inherent in the nature of the deposits. Because of their linear nature, the deposits commonly extend across several property boundaries leading to unorganized extractive development at numerous small pits. On the other hand, because of their form, eskers can be easily and inexpensively extracted and are amenable to rehabilitation and sequential land use.

Undifferentiated Ice-Contact Stratified Drift (IC): This designation may include deposits from several ice-contact, depositional environments which usually form extensive, complex landforms. It is not feasible to identify individual areas of coarse-grained material within such deposits because of their lack of continuity and grain size variability. They are given a qualitative rating based on existing pit and other subsurface data.

Outwash (OW): Outwash deposits consist of sand and gravel laid down by meltwaters beyond the margin of the ice lobes. The deposits occur as sheets or as terraced valley fills (valley trains) and may be very large in extent and thickness. Well developed outwash deposits have good horizontal bedding and are uniform in grain size distribution. Outwash deposited near the glacier's margin is much more variable in texture and structure. The probability of locating useful crushable aggregates in outwash deposits is moderate to high depending on how much information on size, distribution and thickness is available.

Subaqueous Fan (SF): Subaqueous fans are formed within or near the mouths of meltwater conduits when sediment laden meltwaters are discharged into a standing body of water. The geometry of the resulting deposit is fan or lobe shaped. Several of these lobes may be joined together to form a larger, continuous sedimentary body. Internally, subaqueous fans consist of stratified sands and gravels which may exhibit wide variations in grain size distribution. As these features were deposited under glacial lake waters, silt and clay which settled out of these lakes may be associated in varying amounts with these deposits. The variability of the sediments and presence of fines are the main extractive problems associated with these deposits.

Alluvium (AL): Alluvium is a general term for clay, silt, sand, gravel, or similar unconsolidated material deposited during postglacial time by a stream as sorted or semi-sorted sediment, on its bed or on its floodplain. The probability of locating large amounts of crushable aggregate in alluvial deposits is low, and they have gen-

erally low value because of the presence of excess silt- and clay-sized material. There are few large postglacial alluvium deposits in Ontario.

GLACIOLACUSTRINE DEPOSITS

Glaciolacustrine Beach Deposits (LB): These are relatively narrow, linear features formed by wave action at the shores of glacial lakes that existed at various times during the deglaciation of southern Ontario. Well developed lacustrine beaches are usually less than 20 feet (6 m) thick. The aggregate is well sorted and stratified and sand-sized material commonly predominates. The composition and size distribution of the deposit depends on the nature of the source material. The probability of obtaining crushable aggregate is high when the material is developed from coarse-grained materials such as a stony till, and low when developed from fine-grained materials. Beaches are relatively narrow, linear deposits, so that extractive operations are often numerous and extensive.

Glaciolacustrine Deltas (LD): These features were formed where streams or rivers of glacial meltwater flowed into lakes and deposited their suspended sediment. In southern Ontario such deposits tend to consist mainly of sand and abundant silt. However, in near-ice and ice-contact positions, coarse material may be present. Although deltaic deposits may be large, the probability of obtaining coarse material is generally low.

Glaciolacustrine Plains (LP): The nearly level surface marking the floor of an extinct glacial lake. The sediments which form the plain are predominantly fine to medium sand, silt, and clay, and were deposited in relatively deep water. Lacustrine deposits are generally of low value as aggregate sources because of their fine grain size and lack of crushable material. In some aggregate-poor areas, lacustrine deposits may constitute valuable sources of fill and some granular base course aggregate.

GLACIAL DEPOSITS

End Moraines (EM): These are belts of glacial drift deposited at, and parallel to, glacier margins. End moraines commonly consist of ice-contact stratified drift and in such instances are usually called kame moraines. Kame moraines commonly result from deposition between two glacial lobes (interlobate moraines). The probability of locating aggregates within such features is moderate to low. Exploration and development costs are high. Moraines may be very large and contain vast aggregate resources, but the location of the best areas within the moraine is usually poorly defined.

EOLIAN DEPOSITS

Windblown Deposits (WD): Windblown deposits are those formed by the transport and deposition of sand by winds. The form of the deposits ranges from extensive, thin layers to well developed linear and crescentic ridges known as dunes. Most windblown deposits in southern Ontario are derived from, and deposited on, pre-existing lacustrine sand plain deposits. Windblown sediments almost always consist of fine to coarse sand and are usually well sorted. The probabiltiy of locating crushable aggregate in windblown deposits is very low.

Appendix D — Geology of Bedrock Deposits

The purpose of this appendix is to familiarize the reader with the general bedrock geology of southern Ontario (Figure D1), and the potential uses of the various bedrock formations where known. The reader is cautioned against using this information for more specific purposes. The stratigraphic chart (Figure D2) is intended only to illustrate the stratigraphic sequences in particular geographic areas and should not be used as a regional correlation table.

The following description is arranged in ascending stratigraphic order, on a group and formation basis. Precambrian rocks are not discussed. Additional stratigraphic information is included for some formations where necessary. The publications and maps of the Ontario Geological Survey and the Geological Survey of Canada should be referred to for more detailed information. The composition, thickness, and uses of the formations are discussed. If a formation may be suitable for use as aggregate and aggregate suitability test data is available, the data has been included in the form of ranges. The following short forms have been used in presenting this data: PSV = Polished Stone Value, AAV = Aggregate Abrasion Value, $MgSO_4$ = Magnesium Sulphate Soundness Test (loss in percent), LA = Los Angeles Abrasion and Impact Test (loss in percent), Absn = Absorption (percent), BRD = Bulk Relative Density, PN (Asphalt & Concrete) = Petrographic Number for Asphalt and Concrete use.

The ranges are intended as a guide only and care should be exercised in extrapolating the information to specific situations. Aggregate suitability test data has been provided by the Ontario Ministry of Transportation.

Covey Hill Formation (Cambrian)

STRATIGRAPHY: lower formation of the Potsdam Group. COMPOSITION: interbedded non-calcareous feldspathic conglomerate and sandstone. THICKNESS: 0 to 45 feet (0 to 14 m). USES: has been quarried for aggregate in South Burgess Township, Leeds County.

Nepean Formation (Cambro-Ordovician)

STRATIGRAPHY: upper formation of the Potsdam Group. COMPOSITION: thin-bedded to massive quartz sandstone with some conglomerate interbeds and rare shaly partings. THICKNESS: 0 to 100 feet (0 to 30 m). USES: suitable as dimension stone; quarried at Philipsville and Forfar for silica sand; alkali-silica reactive in Portland cement concrete. AGGREGATE SUITABILITY TESTING: PSV = 54-68, AAV = 4-15, $MgSO_4$ = 9-32, LA = 44-90, Absn = 1.6-2.6, BRD = 2.38-2.50, PN (Asphalt & Concrete) = 130-140.

March Formation (Lower Ordovician)

STRATIGRAPHY: lower formation of the Beekmantown Group. COMPOSITION: interbedded quartz sandstone, dolomitic quartz sandstone, sandy dolostone and dolostone. THICKNESS: 60 to 197 feet (18 to 60 m). USES: quarried extensively for aggregate in area of subcrop and outcrop; alkali-silica reactive in Portland cement concrete; lower part of formation is an excellent source of skid-resistant aggregate; suitable for use as facing stone and paving stone. AGGREGATE SUITABILITY TESTING: PSV = 55-60, AAV = 4-6, $MgSO_4$ = 1-17, LA = 15-38, Absn = 0.5-0.9, BRD = 2.61-2.65, PN (Asphalt & Concrete) = 110-150.

Oxford Formation (Lower Ordovician)

STRATIGRAPHY: upper formation of the Beekmantown Group. COMPOSITION: thin- to thick-bedded, microcrystalline to medium-crystalline, grey dolostone with thin shaly interbeds. THICKNESS: 200 to 335 feet (61 to 102 m). USES: quarried in the Brockville and Smith Falls areas and south of Ottawa for use as aggregate. AGGREGATE SUITABILITY TESTING: PSV = 47-48, AAV = 7-8, $MgSO_4$ = 1-4, LA = 18-23, Absn = 0.7-0.9, BRD = 2.74-2.78, PN (Asphalt & Concrete) = 105-120.

Rockcliffe Formation (Middle Ordovician)

STRATIGRAPHY: divided into lower member and upper (St. Martin) member. COMPOSITION: interbedded quartz sandstone and shale; interbedded shaly bioclastic limestone and shale predominating in upper member to the east. THICKNESS: 0 to 410 feet (0 to 125 m). USES: upper member has been quarried east of Ottawa for aggregate; lower member has been used as crushed stone; some high purity limestone beds in upper member may be suitable for use as fluxing stone and in lime production. AGGREGATE SUITABILITY TESTING: PSV = 58-63, AAV = 10-11, $MgSO_4$ = 12-40, LA = 25-28, Absn = 1.8-1.9, BRD = 2.55-2.62, PN (Asphalt & Concrete) = 122-440.

Shadow Lake Formation (Middle Ordovician)

STRATIGRAPHY: eastern Ontario - the basal unit of the Ottawa Group; central Ontario - overlain by the Simcoe Group. COMPOSITION: in eastern Ontario - silty and sandy dolostone with shale partings and minor interbeds of sandstone; in central Ontario - conglomer-

ates, sandstones, and shales. THICKNESS: eastern Ontario - 7 to 10 feet (2 to 3 m); central Ontario - 0 to 40 feet (0 to 12 m). USES: potential source of decorative stone; very limited value as aggregate source.

Gull River Formation (Middle Ordovician)

STRATIGRAPHY: part of the Simcoe Group (central Ontario) and Ottawa Group (eastern Ontario). In central and eastern Ontario the formation is subdivided into upper and lower members; west of Lake Simcoe it is presently subdivided into upper, middle and lower members. COMPOSITION: in central and eastern Ontario the lower member consists of alternating units of limestone, dolomitic limestone, and dolostone, the upper member consists of thin-bedded limestones with thin shale partings; west of Lake Simcoe the lower member is thin- to thick-bedded, interbedded, grey argillaceous limestone and buff to green dolostone, whereas the upper and middle members are dense microcrystalline limestones with argillaceous dolostone interbeds. THICKNESS: 23 to 204 feet (7 to 62 m). USES: quarried in the Lake Simcoe, Kingston, Ottawa, and Cornwall areas for crushed stone; rock from certain layers in eastern and central Ontario has proven to be alkali-reactive when used in Portland cement concrete (alkali-carbonate reaction). AGGREGATE SUITABILITY TESTING: PSV = 41-49, AAV = 8-12, $MgSO_4$ = 3-13, LA = 18-28, Absn = 0.3-0.9, BRD = 2.68-2.73, PN (Asphalt & Concrete) = 100-153.

Bobcaygeon Formation (Middle Ordovician)

STRATIGRAPHY: part of the Simcoe Group (central Ontario) and the Ottawa Group (eastern Ontario), subdivided into upper, middle and lower members; members in eastern and central Ontario are approximately equivalent. COMPOSITION: homogeneous, massive to thin-bedded fine-crystalline limestone with numerous shaly partings in the middle member. THICKNESS: 80 to 285 feet (24 to 87 m). USES: quarried at Brechin, Marysville, and in the Ottawa area for crushed stone; generally suitable for use as granular base course aggregate; rock from certain layers has been found to be alkali-reactive when used in Portland cement concrete (alkali-silica reaction). AGGREGATE SUITABILITY TESTING: PSV = 47-51, AAV = 14-23, $MgSO_4$ = 1-40, LA = 18-32, Absn = 0.3-2.4, BRD = 2.5-2.69, PN (Asphalt & Concrete) = 100-320.

Verulam Formation (Middle Ordovician)

STRATIGRAPHY: part of Simcoe and Ottawa Groups. COMPOSITION: fossiliferous, pure to argillaceous limestone interbedded with calcareous shale. THICKNESS: 105 to 230 feet (32 to 70 m). USES: quarried at Picton and Bath for use in cement manufacture; quarried for aggregate in Mara Township, Simcoe County and in the Belleville-Kingston area; may be unsuitable for use as aggregate in some areas because of its high shale content. AGGREGATE SUITABILITY TESTING: PSV = 43-44, AAV = 9-13, $MgSO_4$ = 4-45, LA = 22-29, Absn = 0.4-2.1, BRD = 2.59-2.70, PN (Asphalt & Concrete) = 120-255.

Lindsay Formation (Middle and Upper Ordovician)

STRATIGRAPHY: part of Simcoe and Ottawa Groups; in eastern Ontario is divisible into an unnamed lower member and the Eastview Member; in central Ontario is divisible into the Collingwood Member (equivalent to portions of the Eastview Member) and a lower member. COMPOSITION: in eastern Ontario the lower member is interbedded, very fine- to coarse-crystalline limestone with undulating shale partings and interbeds of dark grey calcareous shale, whereas the Eastview Member is an interbedded dark grey to dark brown calcareous shale and very fine- to fine-crystalline, petroliferous limestone; in central Ontario Collingwood Member is a black, calcareous shale whereas the lower member is a very fine- to coarse-crystalline, thin-bedded limestone with very thin, undulating shale partings. THICKNESS: 82 to 200 feet (25 to 61 m). USES: in eastern Ontario the lower member is used extensively for aggregate production; in central Ontario it is quarried at Picton, Ogden Point and Bowmanville for cement; may be suitable or unsuitable for use as concrete and asphalt aggregate. AGGREGATE SUITABILITY TESTING: $MgSO_4$ = 2-47, LA = 20-28, Absn = 0.4-1.3, BRD = 2.64-2.70, PN (Asphalt & Concrete) = 110-215.

Blue Mountain and Billings Formations (Upper Ordovician)

STRATIGRAPHY: central Ontario - Blue Mountain Formation includes the upper and middle members of the former Whitby Formation; eastern Ontario - Billings Formation is equivalent to part of the Blue Mountain Formation. COMPOSITION: the Blue Mountain Formation is blue-grey, noncalcareous shale; Billings Formation is dark grey to black, noncalcareous to slightly calcareous, pyritiferous shale with dark grey limestone laminae and grey siltstone interbeds. THICKNESS: Blue Mountain Formation - 140 to 200 feet (43 to 61 m); Billings Formation - 0 to 205 feet (0 to 62 m). USES: Billings Formation may be a suitable source for structural clay products and expanded aggregate; Blue Mountain Formation may be suitable for structural clay products.

Georgian Bay and Carlsbad Formations (Upper Ordovician)

COMPOSITION: in central Ontario the Georgian Bay Formation is composed of interbedded limestone and shale; in eastern Ontario the Carlsbad Formation is composed of interbedded shale, siltstone and bioclastic limestone; THICKNESS: Georgian Bay Formation is 300 to 560 feet (91 to 170 m); Carlsbad Formation - 0 to 610 feet (0 to 186 m). USES: Georgian Bay Formation is

used by several producers in Metropolitan Toronto area to produce brick and structural tile, as well as for making Portland cement; at Streetsville, expanded shale was used in the past to produce lightweight aggregate; Carlsbad Formation is used as a source material for brick and tile manufacturing, has potential as a lightweight expanded aggregate.

Queenston Formation (Upper Ordovician)

COMPOSITION: red, thin- to thick-bedded, sandy to argillaceous shale with green mottling and banding. THICKNESS: 400 to 500 feet (122 to 152 m). USES: there are several large quarries developed in the Queenston Formation in the Toronto-Hamilton region and one at Russell, near Ottawa; all extract shale for brick manufacturing; the Queenston Formation is the most important source material for brick manufacture in Ontario.

Whirlpool Formation (Lower Silurian)

STRATIGRAPHY: lower formation in the Cataract Group in the Niagara Penninsula and the Niagara Escarpment as far north as Duntroon. COMPOSITION: massive, medium- to coarse-grained, argillaceous white to light grey quartz sandstone with thin grey shale partings. THICKNESS: 0 to 25 feet (0 - 8 m). USES: building stone, flagstone.

Manitoulin Formation (Lower Silurian)

STRATIGRAPHY: part of the Cataract Group, occurs north of Stoney Creek. COMPOSITION: thin-bedded, blue-grey to buff-brown dolomitic limestones and dolostones. THICKNESS: 0 to 75 feet (0 to 23 m). USES: extracted for crushed stone in St. Vincent Township, Grey County, and for decorative stone on Manitoulin Island. AGGREGATE SUITABILITY TESTING: no data.

Cabot Head Formation (Lower Silurian)

STRATIGRAPHY: part of the Cataract Group, occurs throughout southern Ontario, south and north of the Niagara Escarpment. COMPOSITION: green, grey and red shales. THICKNESS: 50 to 60 feet (15 to 18 m); USES: potential source of coated lightweight aggregate and raw material for use in manufacture of brick and tile; lack of suitable exposures has limited its use.

Grimsby Formation

STRATIGRAPHY: upper formation of the Cataract Group, is identified on the Niagara Peninsula as far north as Clappison's Corners. COMPOSITION: interbedded sandstone and shale, mostly red. THICKNESS: 0 to 50 feet (0 to 15 m). USES: no present uses.

Thorold Formation (Middle Silurian)

STRATIGRAPHY: lower formation in the Clinton Group on the Niagara Peninsula. COMPOSITION: thick-bedded quartz sandstone. THICKNESS: 7 to 10 feet (2 - 3 m). USES: no present uses.

Neagha Formation (Middle Silurian)

STRATIGRAPHY: part of the Clinton Group on the Niagara Peninsula. COMPOSITION: dark grey to green shale with minor interbedded limestone. THICKNESS: 0 to 5 feet (0 to 2 m). USES: no present uses.

Dyer Bay Formation (Middle Silurian)

STRATIGRAPHY: lower formation in the Clinton Group on Manitoulin Island and northernmost Bruce Peninsula. COMPOSITION: highly fossiliferous, impure dolostone. THICKNESS: 0 to 20 feet (0 to 6 m). USES: no present uses.

Wingfield Formation (Middle Silurian)

STRATIGRAPHY: part of the Clinton Group on Manitoulin Island and northernmost Bruce Peninsula. COMPOSITION: olive green to grey shale with dolostone interbeds. THICKNESS: 0 to 36 feet (0 to 11 m). USES: no present uses.

St. Edmund Formation (Middle Silurian)

STRATIGRAPHY: part of the Clinton Group on Manitoulin Island and northernmost Bruce Peninsula, upper portion previously termed the Mindemoya Formation. COMPOSITION: pale grey to buff brown, micro- to medium-crystalline, thin- to medium-bedded dolostone. THICKNESS: 0 to 85 feet (0 to 26 m). USES: quarried for fill and crushed stone on Manitoulin Island. AGGREGATE SUITABILITY TESTING: $MgSO_4$ = 1-2, LA = 19-21, Absn = 0.6-0.7, BRD = 2.78-2.79, PN (Asphalt & Concrete) = 105.

Fossil Hill and Reynales Formations (Middle Silurian)

STRATIGRAPHY: part of Clinton Group; Fossil Hill Formation occurs in the northern part of the Niagara Escarpment and is approximately equivalent in part, to the Reynales Formation which occurs on the Niagara Peninsula and the Escarpment, as far north as the Forks of the Credit. COMPOSITION: Fossil Hill Formation is fine- to coarse-crystalline dolostone with high silica content; Reynales Formation is thin- to thick-bedded shaly dolostone and dolomitic limestone. THICKNESS: Fossil Hill Formation - 20 to 85 feet (6 to 26 m); Reynales Formation - 0 to 10 feet (0 to 3 m). USES: both formations quarried for aggregate with overlying Amabel and Lockport Formations. AGGREGATE SUITABILITY TESTING: (Fossil Hill Formation on Manitoulin Island) $MgSO_4$ = 41, LA = 29, Absn = 4.1, BRD = 2.45, PN (Asphalt & Concrete) = 370.

Irondequoit Formation (Middle Silurian)

STRATIGRAPHY: part of Clinton Group on the Niagara Peninsula south of Waterdown. COMPOSITION: massive, coarse-crystalline crinoidal limestone. THICKNESS: 0 to 7 feet (0 to 2 m). USES: not significantly utilized.

Rochester Formation (Middle Silurian)

STRATIGRAPHY: part of Clinton Group along the Niagara Peninsula. COMPOSITION: black to dark grey calcareous shale with numerous limestone lenses. THICKNESS: 15 to 60 feet (5 to 18 m). USES: not significantly utilized. AGGREGATE SUITABILITY TESTING: PSV = 69, AAV = 17, $MgSO_4$ = 95, LA = 19, Asbn = 2.2, BRD = 2.67, PN (Asphalt & Concrete) = 400.

Decew Formation (Middle Silurian)

STRATIGRAPHY: part of Clinton Group south of Waterdown along the Niagara Peninsula. COMPOSITION: sandy to shaly dolomitic limestone and dolostone. THICKNESS: 0 to 15 feet (0 to 5 m). USES: too shaly for high quality uses, but is quarried along with Lockport Formation in places. AGGREGATE SUITABILITY TESTING: PSV = 67, AAV = 15, $MgSO_4$ = 55, LA = 21, Absn = 2.2, BRD = 2.66, PN (Asphalt & Concrete) = 255.

Lockport and Amabel Formations (Middle Silurian)

STRATIGRAPHY: Lockport Formation occurs from Waterdown to Niagara Falls, subdivided into 3 formal members: Gasport, Goat Island and Eramosa Members and an informal member (the "Vinemount shale beds"); the stratigraphically equivalent Amabel Formation, found from Waterdown to Cockburn Island, is subdivided into Lions Head, Wiarton/Colpoy Bay, and Eramosa members. COMPOSITION: Lockport Formation is thin- to massive-bedded, fine- to medium-crystalline dolostone; Amabel Formation is thin bedded to massive, medium-crystalline dolostone with reef facies near Georgetown and on the Bruce Peninsula. THICKNESS: (Lockport/ Amabel) 10 to 130 feet (3 to 40 m). USES: both formations have been used to produce lime, crushed stone, concrete aggregate, and building stone throughout their area of occurrence, and are a resource of provincial significance. AGGREGATE SUITABILITY TESTING: PSV = 36-49, AAV = 10-17, $MgSO_4$ = 2-6, LA = 25-32, Absn = 0.4-1.54, BRD = 2.61-2.81, PN (Asphalt & Concrete) = 100-105.

Guelph Formation (Middle Silurian)

STRATIGRAPHY: exposed on the Niagara Escarpment from the Niagara River to the tip of the Bruce Peninsula, mostly present in the subsurface of southwestern Ontario. COMPOSITION: micro-crystalline to medium-crystalline, thick-bedded, soft, porous dolostone, characterized in places by extensive vuggy, porous reefal facies of high chemical purity. THICKNESS: 100 to 170 feet (30 to 52 m). USES: some areas appear soft and unsuitable for use in the production of load-bearing aggregate; this unit requires additional testing to fully establish its aggregate suitability; main use is for dolomitic lime for cement manufacture; quarried near Hamilton and Guelph.

Salina Formation (Upper Silurian)

STRATIGRAPHY: present in the subsurface of southwestern Ontario; rarely exposed at the surface. COMPOSITION: grey and maroon shale, brown dolostone and, in places, salt, anhydrite and gypsum; consists predominantly of evaporitic rich material with up to eight units identifiable. THICKNESS: 370 to 600 feet (113 to 183 m). USES: gypsum mines at Hagersville, Caledonia, and Drumbo; salt is mined at Goderich and Windsor, and is produced from brine wells at Amherstburg, Windsor and Sarnia.

Bertie and Bass Islands Formations (Upper Silurian)

STRATIGRAPHY: Bertie Formation found in southern Niagara Peninsula; Bass Islands Formation, the Michigan Basin equivalent of the Bertie Formation, does not significantly outcrop in Ontario but is present in the subsurface in southwestern Ontario; Bertie Formation represented by Oatka, Falkirk, Scajaquanda, Williamsville, and Akron Members. COMPOSITION: medium- to massive-bedded, micro-crystalline, brown dolostone with shaly partings. THICKNESS: 45 to 160 feet (14 to 49 m). USES: quarried for crushed stone on the Niagara Peninsula at Fort Erie, Cayuga, Hagersville and Dunnville; shaly intervals are unsuitable for use as high specification aggregate because of low freeze-thaw durability; has also been extracted for lime. AGGREGATE SUITABILITY TESTING: PSV = 46-49, AAV = 8-11, $MgSO_4$ = 4-19, LA = 14-23, Absn = 0.8-2.8, BRD = 2.61-2.78, PN (Asphalt & Concrete) = 102-120.

Oriskany Formation (Lower Devonian)

STRATIGRAPHY: basal Devonian clastic unit, found in Niagara Peninsula. COMPOSITION: thick- to massive-bedded, coarse-grained, grey-yellow sandstone. THICKNESS: 0 to 15 feet (0 to 5 m). USES: has been quarried for silica sand, building stone, and armour stone; may be acceptable for use as rip rap, and well cemented varieties may be acceptable for some asphaltic products. AGGREGATE SUITABILITY TESTING: (of a well cemented variety of the formation) PSV = 64, AAV = 6, $MgSO_4$ = 2, LA = 29, Absn = 1.2-1.3, BRD = 2.55, PN (Asphalt & Concrete) = 107.

Bois Blanc Formation (Lower Devonian)

STRATIGRAPHY: Springvale Sandstone Member forms the lower portion of formation. COMPOSI-

TION: a cherty limestone with shale partings and minor interbedded dolostones; Springvale Sandstone Member is a medium- to coarse-grained, green glauconitic sandstone with interbeds of limestone, dolostone and brown chert. THICKNESS: 10 to 130 feet (3 to 40 m). USES: quarried at Hagersville, Cayuga, and Port Colborne for crushed stone; material generally unsuitable for concrete aggregate because of high chert content. AGGREGATE SUITABILITY TESTING: PSV = 48-53, AAV = 3-7, $MgSO_4$ = 3-18, LA = 15-22, Absn = 1.3-2.8, BRD = 2.50-2.70, PN (Asphalt & Concrete) = 102-290.

Onondaga Formation (Middle Devonian)

STRATIGRAPHY: correlated to part of the Detroit River Group; occurs on the Niagara Peninsula from Simcoe to Niagara Falls; contains the Edgecliff, Clarence, and Moorehouse Members. COMPOSITION: medium-bedded, fine- to coarse-grained, dark grey-brown or purplish-brown, variably cherty limestone. THICKNESS: 60 to 82 feet (18 to 25 m) USES: quarried for crushed stone on the Niagara Peninsula at Welland and Port Colborne; high chert content makes much of the material unsuitable for use as concrete aggregate and asphaltic concrete; has been used as a raw material in cement manufacture. AGGREGATE SUITABILITY TESTING: (Clarence and Edgecliff Members) $MgSO_4$ = 1-6, LA = 16.8-22.4, Absn = 0.5-1.1, PN (Asphalt & Concrete) = 190-276.

Amherstburg Formation (Middle Devonian)

STRATIGRAPHY: part of Detroit River Group; correlated to Onondaga Formation in Niagara Penninsula; contains Sylvania Sandstone Member and Formosa Reef Limestone. COMPOSITION: bituminous, bioclastic, stromatoporoid-rich limestone and dolostone with grey chert nodules; Formosa Reef Limestone is high purity (calcium rich) limestone; Sylvania Sandstone Member is quartz sandstone. THICKNESS: 0 to 165 feet (0 to 50 m); Formosa Reef Limestone up to 85 feet (26 m). USES: cement manufacture, agricultural lime, aggregate. AGGREGATE SUITABILITY TESTING: PSV = 57, AAV = 19, $MgSO_4$ = 9-35, LA = 26-52, Absn = 1.1-6.4, BRD = 2.35-2.62, PN (Asphalt & Concrete) = 105-300.

Lucas Formation (Middle Devonian)

STRATIGRAPHY: part of the Detroit River Group in southwestern Ontario; includes the Anderdon Member which, in the Woodstock Beachville area, may constitute the bulk of the formation. COMPOSITION: light brown or grey-brown dolostone with bituminous laminations and minor chert; Anderdon Member consists of very high purity (calcium-rich) limestone. THICKNESS: 130 to 246 feet (40 to 75 m). USES: most important source of high-purity limestone in Ontario; used as calcium lime for metallurgical flux and for the manufacture of chemicals; rock of lower purity is used for cement manufacture, agricultural lime and aggregate; Anderdon Member is quarried at Amherstburg for crushed stone. AGGREGATE SUITABILITY TESTING: PSV = 46-47, AAV = 15-16, $MgSO_4$ = 2-60, LA = 22-47, Absn = 1.1-6.5, BRD = 2.35-2.40, PN (Asphalt & Concrete) = 110-160.

Dundee Formation (Middle Devonian)

STRATIGRAPHY: few natural outcrops, largely in the subsurface of southwestern Ontario. COMPOSITION: fine- to medium-crystalline, brownish-grey, medium- to thick-bedded, dolomitic limestone with shaly partings sandy layers, and chert in some areas. THICKNESS: 50 to 100 feet (15 to 30 m). USES: quarried near Port Dover and on Pelee Island for crushed stone; used at St. Marys as a raw material for Portland cement. AGGREGATE SUITABILITY TESTING: $MgSO_4$ = 1-28, LA = 22-46, Absn = 0.6-6.8, PN (Asphalt & Concrete) = 125-320.

Marcellus Formation (Middle Devonian)

STRATIGRAPHY: subsurface unit, mostly found below Lake Erie and extending into the eastern U.S.A., pinches out in the Port Stanley area. COMPOSITION: black, bituminous shales. THICKNESS: 0 to 15 feet (0 to 5 m). USES: no present uses.

Bell Formation (Middle Devonian)

STRATIGRAPHY: lowest formation of the Hamilton Group, no outcrop in Ontario. COMPOSITION: soft blue and grey calcareous shale. THICKNESS: 0 to 30 feet (0 to 9 m). USES: no present uses.

Rockport Quarry Formation (Middle Devonian)

STRATIGRAPHY: part of the Hamilton Group; no outcrop in Ontario. COMPOSITION: grey-brown, very fine-grained limestone with occasional shale layers. THICKNESS: 0 to 20 feet (0 to 6 m). USES: no present uses.

Arkona Formation (Middle Devonian)

STRATIGRAPHY: part of the Hamilton Group. COMPOSITION: blue-grey, plastic, clay shale with occasional thin and laterally discontinuous limestone lenses. THICKNESS: 15 to 120 feet (5 to 37 m). USES: has been extracted at Thedford and near Arkona for the production of drainage tile.

Hungry Hollow Formation (Middle Devonian)

STRATIGRAPHY: part of the Hamilton Group. COMPOSITION: grey crinoidal limestone and soft, fossiliferous calcareous shale. THICKNESS: 0 to 6 feet (0 to 2 m). USES: suitable for some crushed stone and fill with selective quarrying. AGGREGATE SUITABILITY TESTING: No data.

Widder Formation (Middle Devonian)

STRATIGRAPHY: part of the Hamilton Group. COMPOSITION: mainly soft, grey, fossiliferous calcareous shale interbedded with blue-grey, fine-grained fossiliferous limestone. THICKNESS: 0 to 45 feet (0 to 14 m). USES: no present uses.

Ipperwash Formation (Middle Devonian)

STRATIGRAPHY: upper formation of the Hamilton Group; very limited distribution. COMPOSITION: medium- to coarse-grained, grey-brown, bioclastic limestone. THICKNESS: 5 to 45 feet (2-14 m). USES: no present uses.

Kettle Point Formation (Upper Devonian)

STRATIGRAPHY: occurs in a band between Sarnia and Erieau; small part overlain by Port Lambton Group rocks in extreme northwest. COMPOSITION: black, highly fissile, organic-rich shale with minor interbeds of grey-green silty shale. THICKNESS: 0 to 200 feet (0 to 61 m). USES: possible source of fill; possible source of material for use as sintered lightweight aggregate.

Bedford Formation (Upper Devonian)

STRATIGRAPHY: lower formation of the Port Lambton Group. COMPOSITION: soft, grey shale. THICKNESS: 0 to 108 feet (0 to 33 m). USES: no present uses.

Berea Formation (Upper Devonian)

STRATIGRAPHY: middle formation of the Port Lambton Group; not known to occur at surface in Ontario. COMPOSITION: grey, fine- to medium-grained sandstone, often dolomitic and interbedded with grey shale and siltstone. THICKNESS: 0 to 197 feet (0 to 60 m). USES: no present uses.

Sunbury Formation (Upper Devonian)

STRATIGRAPHY: upper formation of the Port Lambton Group; not known to occur at surface in Ontario. COMPOSITION: black shale. THICKNESS: 0 to 66 feet (0 to 20 m). USES: no present uses.

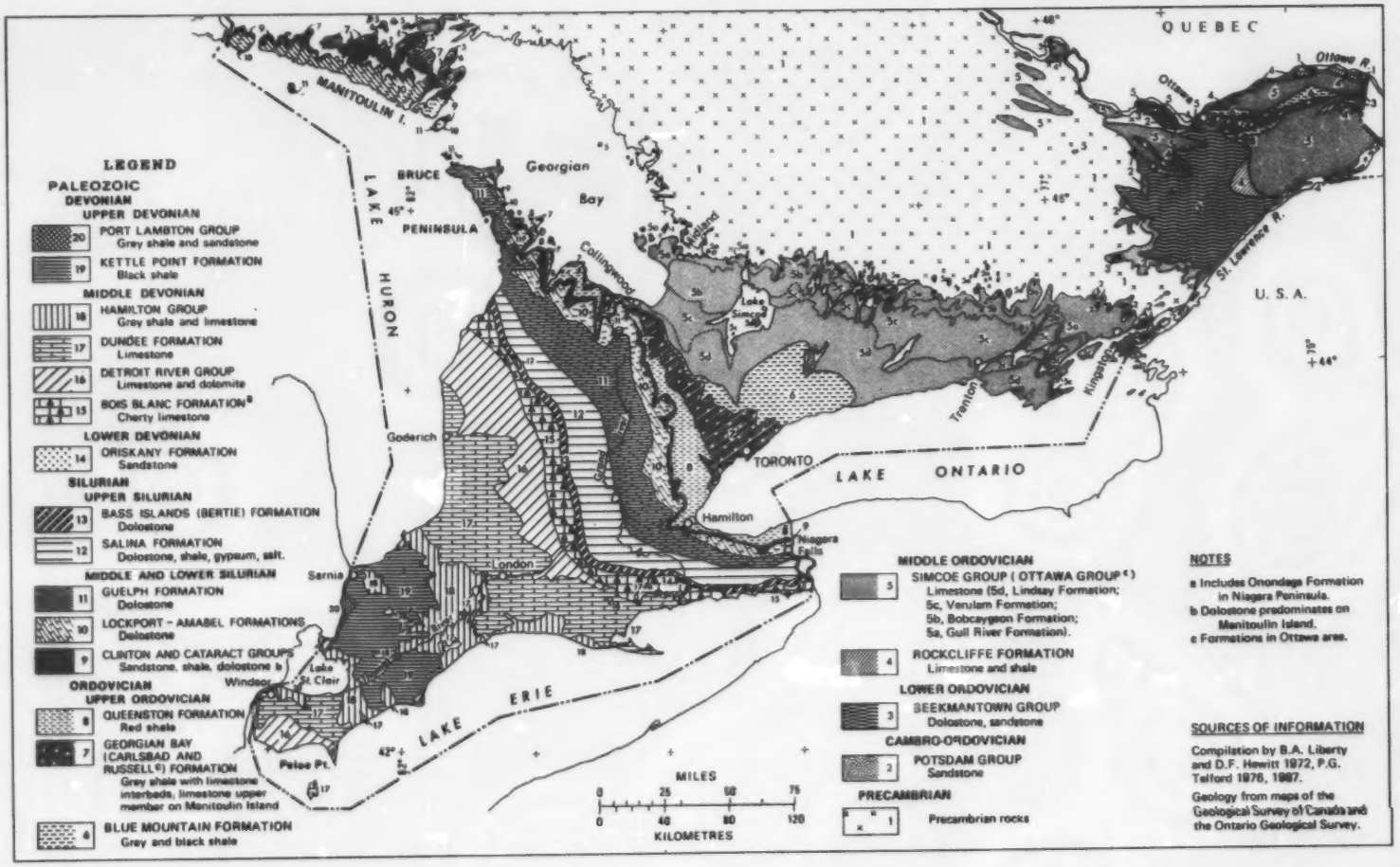

Figure D1. Bedrock Geology of Southern Ontario.

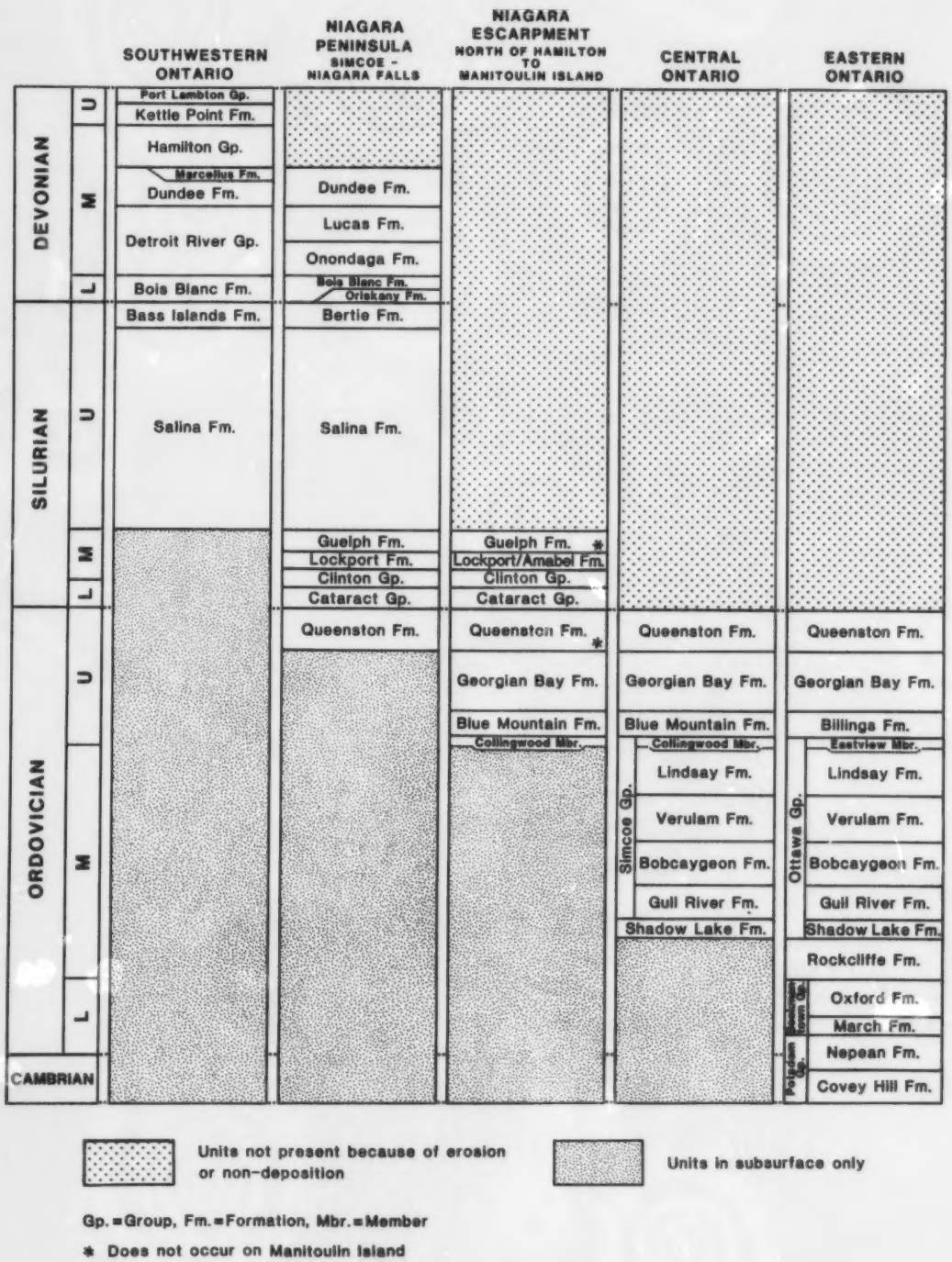

Figure D2. Exposed Paleozoic Stratigraphic Sequences in Southern Ontario
(adapted from: Bezys, R. K., and Johnson, M.D. 1988. The geology of the Paleozoic formations utilized by the limestone industry of Ontario; The Canadian Mining and Metallurgical Bulletin v.81, no.912, p.49–58).

Appendix E — Aggregate Quality Test Specifications

Four types of aggregate quality tests are often performed by the Ontario Ministry of Transportation on sampled material. A description of Table E1 and the specification limits for each test are given in this appendix. Although a specific sample meets or does not meet the specification limits for a certain product, it may or may not be acceptable for that use based on field performance. Additional quality tests other than the four major tests listed in this appendix can be used to determine the suitability of an aggregate. The tests are performed by the Soils and Aggregates Section, Engineering Materials Office, Ontario Ministry of Transportation.

Absorption capacity: Related to the porosity of the rock types of which an aggregate is composed. Porous rocks are subject to disintegration when absorbed liquids freeze and thaw, thus decreasing the strength of the aggregate.

Los Angeles abrasion and impact test: This test measures the resistance to abrasion and the impact strength of aggregate. This gives an idea of the breakdown that can be expected to occur when an aggregate is stockpiled, transported, and placed. Values less than about 35% indicate potentially satisfactory performance for most concrete and asphalt uses. Values of more than 45% indicate that the aggregate may be susceptible to excessive breakdown during handling and placing.

Magnesium sulphate soundness test: This test is designed to simulate the action of freezing and thawing on aggregates. Those aggregates which are susceptible to freezing and thawing will usually break down and give high losses in this test. Values greater than about 12 to 15% indicate potential problems for concrete and asphalt coarse aggregate.

Petrographic examination: Individual aggregate particles in a sample are divided into categories good, fair, poor, and deleterious, based on their rock type (petrography) and knowledge of past field performance. A petrographic number (PN) is calculated. The higher the PN, the lower the quality of the aggregate.

TABLE E1. SELECTED QUALITY REQUIREMENTS FOR MAJOR AGGREGATE PRODUCTS.

	TYPE OF TEST				
	COARSE AGGREGATE				FINE AGGREGATE
TYPE OF MATERIAL	Petrographic Number Maximum	Magnesium Sulphate Soundness – Max. % Loss	Absorption Maximum %	Los Angeles Abrasion Maximum % Loss	Magnesium Sulphate Soundness Maximum % Loss
Granular Base A	200	–	–	60	–
16 mm Crushed Type 'A'	160	–	–	35	–
16 mm Crushed Type 'B'	200	–	–	60	–
Granular Subbase B	250	–	–	–	–
Granular Subbase C	250	–	–	–	–
Granular Subbase D	–	–	–	–	–
Hot Mix – HL 1	100	5	1.0	15	16
Hot Mix – HL 2	–	–	–	–	20
Hot Mix – HL 3	135	12	1.75	35	16
Hot Mix – HL 4	160	12	2.0	35	20
Hot Mix – HL 8	160	15	2.0	35	20
Structural Concrete and Concrete Base	140	12	2.0	35	16
Pavement Concrete and Exposed Structure Deck	125	12	2.0	35	16

(Ministry of Transportation Forms 1002, 1003 and 1010)

CONVERSION FACTORS FOR MEASUREMENTS IN ONTARIO GEOLOGICAL SURVEY PUBLICATIONS

Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
		LENGTH			
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709 7	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
		AREA			
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
		VOLUME			
1 cm^3	0.061 02	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.308 0	cubic yards	1 cubic yard	0.764 555	m^3
		CAPACITY			
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
		MASS			
1 g	0.035 273 96	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 75	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 62	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 908 8**	t
		CONCENTRATION			
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

	Multiplied by	
1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

Note: Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries, published by the Mining Association of Canada in co-operation with the Coal Association of Canada.

MAPS
NOT
FILMED

CARTES
OMISES